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DISASTER RISK REDUCTION MANAGEMENT IN THE CITY OF TEHRAN: HOW DO CONSTRUCTION PRACTITIONERS PREPARE FOR A POTENTIAL EARTHQUAKE?

AN INVESTIGATION BASED ON RESEARCH IN TEHRAN-IRAN

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DISASTER RISK REDUCTION MANAGEMENT IN THE CITY OF TEHRAN: HOW DO CONSTRUCTION PRACTITIONERS PREPARE FOR A POTENTIAL EARTHQUAKE?

By: Amir Reza Golestaneh

CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

Signed by: Amir Reza Golestaneh

THE UNIVERSITY of LIVERPOOL

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ABSTRACT

Natural disasters such as earthquakes are disruptive environmental events which severely impact the livelihoods of people, the integrity of infrastructures and buildings, and the global economy. The identification and comprehension of the total effects of earthquakes upon infrastructures and buildings along with working towards improving seismic protection methods and earthquake resistant buildings has been extensively studied by many researchers. Numerous studies have focused on identifying the effects of earthquakes in urban areas as the collapse of buildings during earthquakes poses one of the greatest threats to human life.

The capital city of Iran, Tehran, is an earthquake-prone zone located in the active Alpine-Himalayan seismic belt and has experienced many earthquakes over the centuries. Due in part to rapid population growth, the increase of urban development and insufficient safety regulations, levels of human vulnerability to the impacts of a strong earthquake have risen steadily as the city continues to develop. In order to mitigate the potential impact of such an event, there are several strategies which should be implemented in the further urban development of the city.

This thesis serves to present various strategies relating to Tehran's construction practitioners and engineering communities in their mission to reduce the adverse impacts of a strong earthquake. In order to develop an effective overall strategy, it is essential to first develop the multidisciplinary methods of disaster mitigation planning such as the application of seismic standards and codes in construction, the retrofitting of existing buildings and infrastructures to improve vulnerable areas, the advancement of disaster management

practices to address risk management rather than being limited to crisis management, the improvement of emergency response capabilities, the commission of local authorities to provide oversight and enforcement of construction regulations and seismic codes, the promotion of ethical practice in the construction industry, the establishment of a national insurance program to provide coverage for the long-term effects of natural disasters and the formation of an accountable disaster management agency with an unobstructed manifesto.

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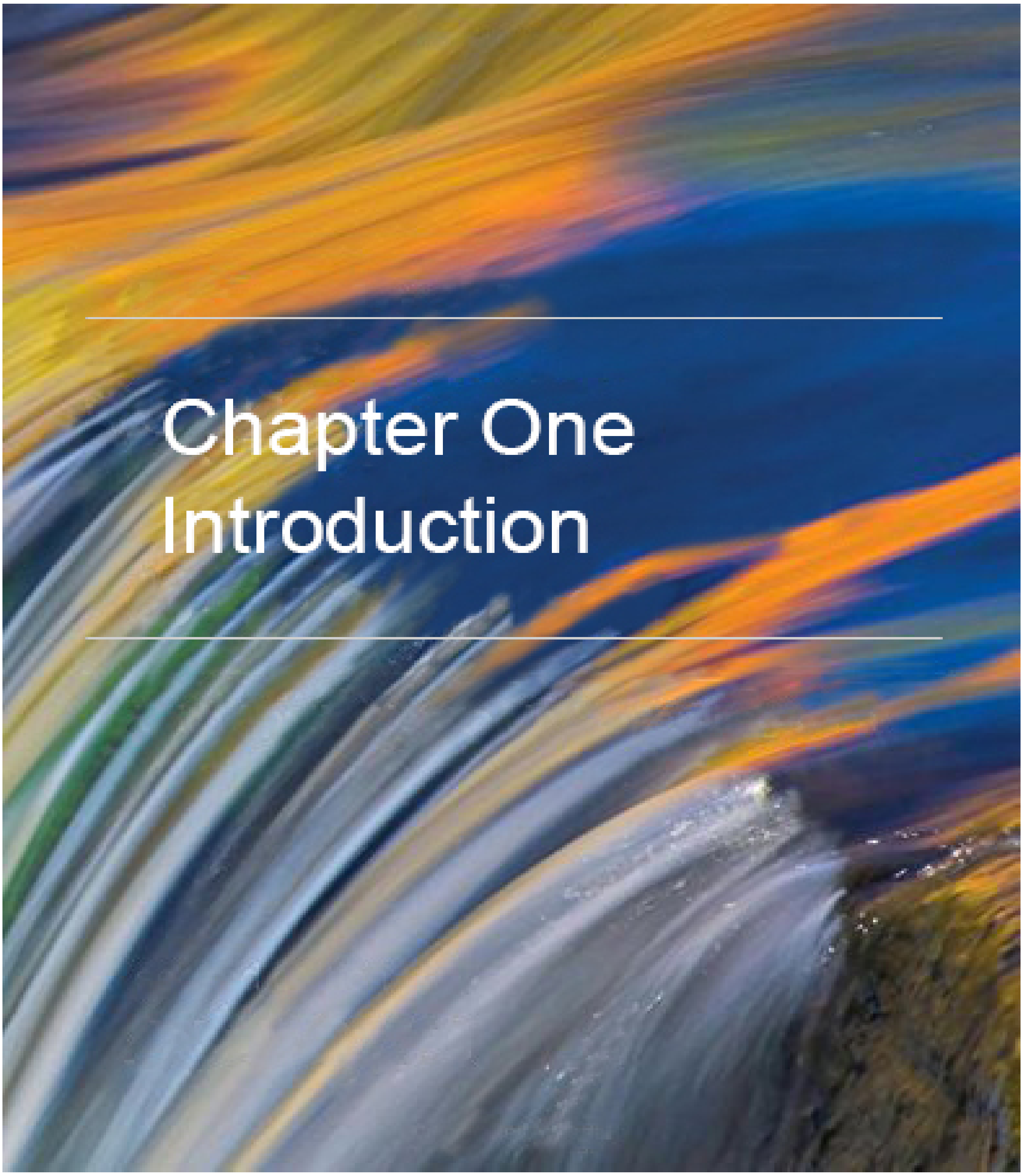


Chapter One
Introduction

CHAPTER 1: INTRODUCTION

1.1. Introduction

People across the world are at risk of encountering natural disasters in their daily lives. The damages of such disasters are not only detrimental to human life but also destructive to the environment and economies. Between the period of 2000 and 2012, The United Nation Office for Disaster and Risk Reduction (UNISDR) identified 5,000 natural disasters internationally which affected approximately 2.9 billion people (UNISDR, 2016). Their report estimated that these 5,000 natural disasters resulted in economic damages of USD 1.7 trillion and 1.2 million deaths.

Earthquakes are one form of a natural disaster which has the potential to deliver devastating effects. According to the UNISDR, the number of human deaths arising from earthquakes, between the period of 2002 and 2011, were approximately 68,000 with a further 7.9 million individuals being drastically affected (UNISDR, 2016). Countries situated in high-risk seismic zones are the most vulnerable to the effects of earthquakes. Moreover, according to the statistics presented by Mansouri, Fatemi Aghda and Safari (2002), developing countries are also at higher risk of the effects of earthquake disasters. One such developing country is Iran which "*is in a region of active faults and hence high seismicity (over more than 90% of the country) as one of the highest-seismic-hazard areas in the world*" (Ghafory-Ashtiany, 2014, p.266).

The importance of risk reduction planning for earthquakes is determined by studying the number of damages derived from a disaster. The Federal Emergency Management Agency (FEMA) (1985), for instance, state that earthquakes impact entire societies, meaning that the community as a whole is placed at risk, but economic, social and cultural variables can alter the degree of impact. Several scholars have performed research in order to evaluate how the impacts of earthquakes should be managed (e.g., Sawada, 2007; Olson and Dash Wu, 2010). Norris et al. (2002), contend that identifying vulnerability is a critical step towards the management and reduction of earthquake impacts. The next step is to implement an effective model for disaster management in the region. The parameters for disaster management can be organized into four categories which include "*mitigation, preparedness (before an event), response and recovery (after an event)*" (Hidayat and Egbu, 2010, p.1270). Each of these steps plays a significant role in the disaster management process and are fundamentally linked, but most crucial to the ability of any society or governing body to reduce the impacts of an earthquake is the mitigation stage (Alexander, 2000).

The majority of research and implementation relating to earthquake risk reduction is focused upon these four categories, with the mitigation phase being the most pertinent to the engineering community. There are several key issues which contribute to the effectiveness, or lack thereof, of mitigating vulnerability through disaster management. These include but are not limited to ethical issues, outdated regulations, poor construction practices, neglected disaster management systems and decisions made between the construction of new buildings versus the retrofit of pre-existing structures. This study will investigate the inherent problems within the context of construction practice relating to earthquake-proof buildings which the author has encountered in the city of Tehran.

1.2. Statement of the Problem

1.2.1. Background

According to the United Nations Development Programme (UNDP, 2013), amongst the 43 disaster locations situated across various active fault zones, Iran is ranked as the 34th nation most vulnerable to seismic events. Figure 1-1 illustrates that active fault-lines span greater than 90% of the country, which is one of the most seismically active countries in the world (Hessami, Jamali, and Tabasi, 2003).

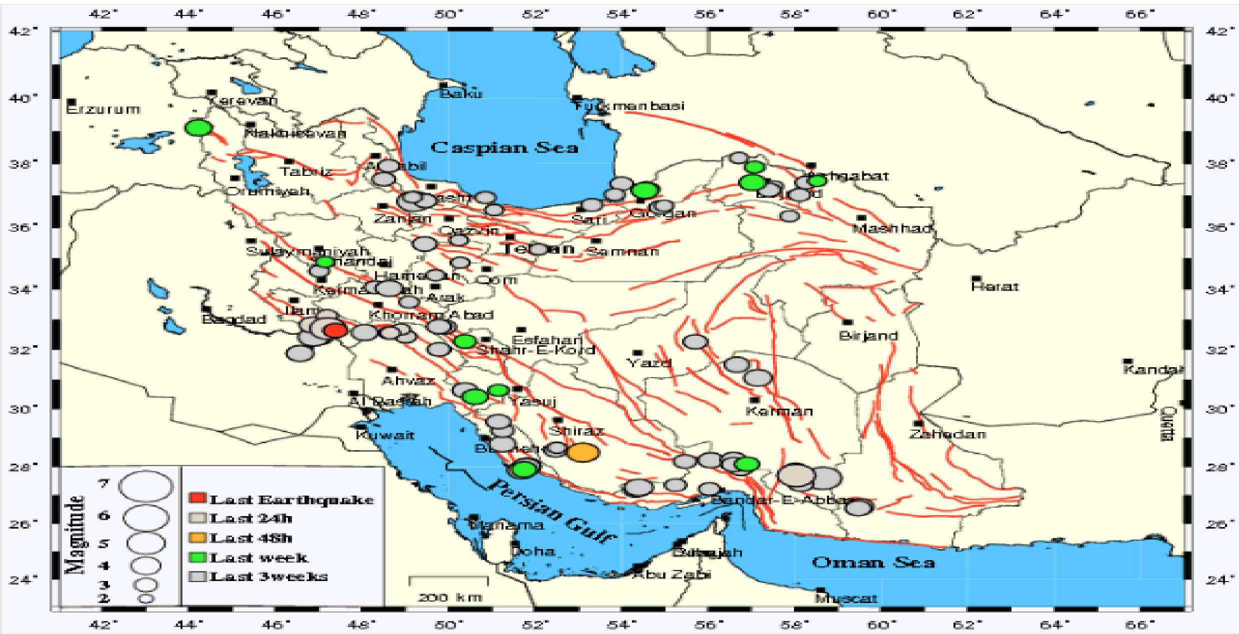


Figure 1-1 Map of active faults in Iran (Hessami, Jamali, and Tabasi, 2003)

In the last century alone, Iran has been subjected to over 22 major earthquakes having claimed the lives of over 150,000 people, also resulting in extensive economic damages and thousands of villages and towns having been destroyed (Ghafory-Ashtiany, 1994). The seismic records of recent decades indicate that there is a high probability for the reoccurrence of seismic events within Iran. Seismologist forecasts explain that "*an average of one earthquake per year with a magnitude of 6.0 Richter or higher and an event with a magnitude of at least 7.0 Richter every ten years will occur in the country*" (Amini Hosseini et al., 2009 cited in Amini Hosseini et al.,2013, p. 517). Iran also maintains high susceptibility to the economic and social damages of an earthquake. Table 1-1 lists the top 10 seismic events which have occurred in Iran since 1990 (EM-DAT 2016).

Table 1-1: Top 10 seismic events in Iran for the period 1990 to 2016 by number of deaths

No.	Date	Location	No. of Deaths	Total Affected People	Est. Damage (US$ Millions)
1	1990	Manjil-Rudbar	40,000	710,000	8,000,000
2	2003	Bam	26,796	267,628	500,000
3	1997	Qayen	1,568	74,600	100,000
4	1997	Ardabil	1,100	38,600	76,000
5	2005	Zarand	612	94,766	80,000
6	2012	Tabriz	306	61,546	500,000
7	2002	Qazvin	227	111,300	300,000
8	1997	Bojnurd	100	84,500	42,262
9	2006	Doroud, Borujerd	63	161,418	600,000
10	2013	Bushehr	37	4,350	165,000

[EM-DAT, 2016]

1.2.2. The Likelihood of an Earthquake in Tehran

The city of Tehran, being one of the largest cities in Iran, totals an area of 1,300 square kilometres spread along the southern slopes of the Alborz Mountains in the northern-central region of the country (Figure 1-2). Due to a combination of socioeconomic and political factors, the population of Tehran has increased rapidly over the last decades, achieving the status of the most populous city both within Iran and the middle-east region at large. A report furnished by the Statistical Centre of Iran (2011) indicates that the population of Tehran is approximately 10 million while the wider metropolitan area reaches approximately 12 million. Being the nation's capital, Tehran is the centre of administrative, judicial, political, social and economic affairs.

Figure 1-2 Location of Tehran

The inhabitants of Tehran have been affected by the occurrence of natural disasters such as Earthquakes and Flooding in the past (Iran National Report, 2006). The number of fault-lines located within the immediate vicinity of the city creates an exceptional susceptibility to the occurrence of dangerous earthquakes (Figure 1-3).

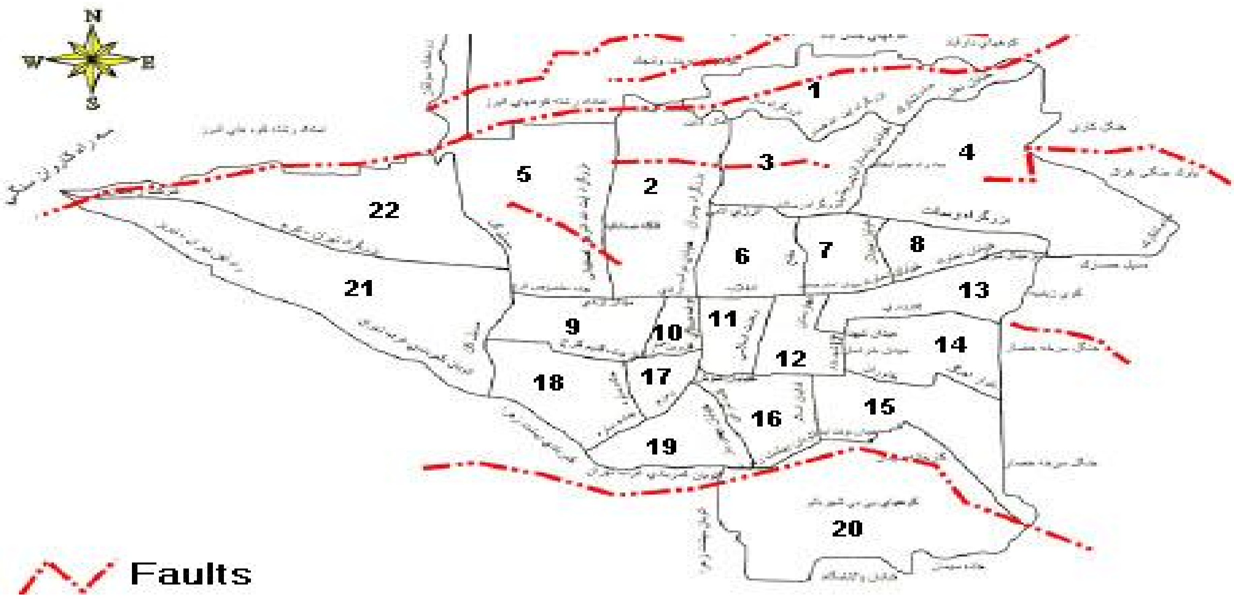


Figure 1-3 Fault map of Tehran (Ashtiani and Amini Hosseini, 2005)

Arian et al. (2012) expressed that seven primary faults understood by seismologists in Tehran. The movement possible equivalent method represented by Lee, Hou, and Ye (1997) was utilized to calculate the Fault Movement Potential (FMP) of these seven faults. Table 1-2 confirms that the area with the highest FMP is the northern region of Tehran.

Table 1-2 *Movement potential of Tehran's seven main faults (Arian et al., 2012)*

NO.	FAULT NAME	FMP
1	Mosha Fault	0.2 - 0.7
2	North Tehran Fault	0.9 - 0.4
3	Kahrizak Fault	0.4
4	Parchin Fault	0.1
5	Pishva Fault	0.2 - 0.3
6	Kuh-e Sorkh Fault	0.3 - 0.7
7	Garmsar Fault	0.4 - 0.6

Ashtiani and Amini Hosseini (2005) propose that according to several seismological studies, and despite the interlude of significant earthquakes within the city over the last century, there is a strong probability that Tehran will be subject to further earthquake occurrences in the proximate future. The rapid urban population growth of Tehran has led the city to pursue development and construction in high-risk areas which would otherwise be considered inappropriate given the topographic and tectonic properties of the region. Although some safety measures have been implemented to protect against earthquake hazards, these programs commonly suffer from a combination of poor implementation by the local authorities and misapprehension by the public.

It is palpable that under the current conditions the occurrence of a significant earthquake in Tehran would indeed result in the severe loss of human life in conjunction with economic and environmental damages of substantial proportions. Previous studies have ascertained that the majority of human fatalities occurring during earthquakes is the result of building collapse deriving from inadequate construction methodology rather than of the direct environmental incident of the earthquake itself (Seismic Safety Commission, 1987, p.1; NIST, 2010). The apparent negligence of Iranian scholars and construction practitioners in failing to employ optimal construction management methods, reveals the importance of further scrutiny in this subject.

1.2.3. Significance of the Study

Under the ordinance of Tehran Municipality, the Tehran Disaster Mitigation and Management Center (TDMMC) was established in July 2004 to provide oversight for disaster mitigation planning. Thereafter, in February of 2005, the First International Conference on Integrated Natural Disaster Management (INDM) was held in Tehran. Despite these efforts to implement a formal approach towards disaster planning and mitigation, it is evident that there remains a complete absence of coherent planning (TDMMO, 2016). The earthquake geology of Iran has frequently been studied by the head of the Department of Earth and Science of the University of Cambridge, Professor James Jackson. He has also collaborated with the Geological Survey of Iran, a governmental body responsible for the evaluation and identification of earthquake-related hazards. In February of 2014, Professor Jackson attended the 1st International and 32nd National Geoscience Congress in the city of Tabriz, Iran. An interview with Professor Jackson, reproduced below, clearly sets out the seismic issues faced in Tehran:

> *"**What risks does Tehran face?** Tehran is in a geological location that is well understood. It is close to faults that are known to move in earthquakes, and Tehran has suffered four large earthquakes that we know about in the last 1,000 years. There will be another massive earthquake in Tehran, and Tehran has grown enormously. Tehran is vulnerable because of the quality of its buildings, which is well understood by everybody."*
>
> ***"What would be the consequences of a major earthquake in Tehran?** It would be a catastrophe. It is [evident] from [significant] earthquakes in other countries that engineers and architects can design buildings that stay up in even the biggest earthquakes. The problem is corruption and a lack of education. The reason buildings collapse is because of poor construction, and builders are trying to save money by cutting corners. That is fatal, always. What is required is that the public is sufficiently educated, so they will not tolerate that."*
>
> ***"What progress has the Iranian government made in responding to the situation?** If you read the statements produced by the Geological Survey of Iran, which comes under the Ministry of Mines, they give you some idea of where Iran is on the earthquake science spectrum. These statements are remarkable in their common sense. They came up as the last item of a meeting to which the Geological Survey had asked about a dozen foreigners. I was one of them. They wanted the foreigners to endorse this statement describing how they saw the situation. It is very strong on how "earthquake prediction" is not only not*

possible, but it is positively harmful because it takes away responsibility from governments and politicians. It emphasizes the need to educate the public, the construction industry, and scientists so that everyone works together toward making better buildings. These points seem obvious, but they are the reason that countries like Japan and New Zealand are resilient—because all those things have happened." (Brown, 2014)

In conjunction with the above issues, there has not been sufficient controls implemented to ensure that building practitioners obey both ethical standards and adequate construction methods. This neglect has resulted in a significant amount of developments appearing in high-risk fault zones such as Niavaran. It is common practice in Tehran that construction is allowed to proceed unsupervised and in some cases on lands without regulated ownership or title registrations. It has also been prevalent that governmental and public administrators have failed to react appropriately in the wake of previous natural disasters such as the Bam earthquake of 2003. It seems apparent that the local engineering community does not have any programs in place for the implementation of earthquake mitigation through improved construction design or execution, and they appear to have no interest to in engaging in proactive disaster management schemes. A major concern on this subject is the ethical stance of engineering practitioners towards the balance between earthquake effect mitigation and construction costs. All of these issues confirm that it is imperative the engineering community devote greater attention to this subject.

1.3. Personal and Professional Motivation

The Manjil-Rudbar earthquake of 1990 occurred during the time of the author's studies in civil engineering at university in the northern region of Iran. The earthquake destroyed over 700 villages and the cities of Manjil, Lushan, and Rudbar. The University dormitories, located approximately 75 kilometers from the event epicenter, were also affected by the earthquake. However, the most severely affected areas were undoubtedly the cities of Manjil and Rudbar. On the following day, the university decided to send a number of students to help with the emergency efforts and provide relief for the victims of the earthquake, of which the author was one such volunteer. It was a grievously profound event for everyone involved. A majority of the various buildings were damaged by the earthquake, under which countless inhabitants lay either deceased or trapped wihtin the debris. Please see Figure 1-4. Photograph Credit: S. Hashemi.

Figure 1-4 Building's destruction in Manjil-Rudbar earthquake, 1990

Four months after the event, the university research team, of which the author was a volunteer member, were dispatched to assess the extent of the damage caused by the earthquake and to identify any key contributing factors which may have resulted in the acute damages which had occurred. The contributing factors identified during the investigation included:

1- **Construction materials:** The use of brittle materials such as brick and timber in the construction of traditional structures were inappropriate and did not possess any earthquake resistant properties.
2- **Construction techniques, and workmanship**: In steel frame buildings, columns had been constructed with unreinforced shear walls and poor welding and workmanship were observed in the metallurgy. Heavy masonry had been used inappropriately and without proper support to the roofs, flooring, and ceilings. Any supporting beams which had been provided were often not properly interconnected.
3- **Inadequate design and detailing:** Earthquake resistant design codes had not been effectively implemented. The standards of construction were inconsistent with acceptable building codes. The interconnection of beams, columns, and slabs had been poorly executed and did not exhibit any evidence of qualified supervision. Figure 1-5 illustrates the poor construction of nonductile concrete framed buildings.

   Photograph Credit: M. Mehrain, Dames, and Moore.

Figure 1-5 Poor performance of buildings due to inadequate design and detailing in Manjil-Rudbar earthquake, 1990

The report produced by the university research team concluded that inadequate building design, poor construction methods, and the absence of qualified supervision, can significantly increase the level of earthquake vulnerability. The historical record of earthquakes reveals that the adverse effects and extent of the disaster does not depend on the duration, nature or magnitude of the environmental hazard, but instead is dependant upon the resistance capabilities of affected structures. Thus, the author maintains a firm conviction that the various qualified professionals such as seismologists, architects, construction engineers along with the concerned governing bodies must work together in cooperation to not only mitigate vulnerability by improving society's capability to provide appropriate disaster management models but also to improve the design and execution of construction by developing appropriate seismic resistant structures.

1.4. Research Objectives and Questions

The unpredictable nature of earthquakes, in comparison to other natural disaster events, offers greater challenges in predicting potential impacts on human life and the environment. Based on past evidence from earthquakes within Iran, it is recognized that the constitution of buildings is a key factor which may contribute to the loss of life incurred during an earthquake. (e.g., Arian et al., 2012; Amiri et al., 2003; Manafpour, 2003; Hosseini and Amini Hosseini, 2008). Thus, the importance of rigorous study in regards to construction methods and how construction engineers can become better prepared to implement proactive seismic vulnerability reduction methods becomes evident. Hence, the core question that this research proposes to answer is: ***"To assess the state of awareness and current practice of construction engineers and the construction industry to prepare for seismic events and explore the gap between the best construction practice and the context of such practices in the city of Tehran."***

This research intends to investigate potential obstructions which construction engineers may encounter in their attempts to implement earthquake risk reduction methods into general construction practices within the city of Tehran. It is important to understand the contribution made by this research towards the promotion of creativity, insight, knowledge and understating of this research topic by construction engineers. Several questions must be explored in order to clarify why construction communities are not implemented risk management plan in the city of Tehran.

Previous studies have suggested that Tehran does maintain a functional disaster risk management plan (e.g., Ashtiani and Amini Hosseini, 2005; Amini Hosseini and Jafari, 2007; JICA, 2000). However, it is evident that Iran's risk management organization is a novice body whose methods and planning remain ill-defined and require greater attention. Therefore, the principal objectives of this study are to:

1- Determine the problems encountered by construction practitioners, the subsequent impacts which such problems may impose on the stability of buildings in the event of an earthquake, and the significance of each identified problem on the performance of buildings.
2- Investigate the processes of construction practices and engineering practitioners' role with an intent to identify the factors which may affect the seismic resistance of buildings and the degree of significance of such factors.
3- Determine the effectiveness of Tehran's current disaster management and risk reduction strategies and their effects on the capability of construction engineers to prepare for earthquakes and their adverse impacts.

The study of construction practices relating to seismic-resistant buildings in Tehran is helpful in the following ways:

1- To establish the scope and methodology of engineering practices relating to seismic standards in the city of Tehran for the benefit of the entire construction industry and decreased vulnerability.

2- To improve the ethical practices of construction engineers by providing comprehensive knowledge of the factors affecting ethical behaviour within the construction sector.
3- To enhance the performance of construction engineers in terms of quality improvement and cost optimization relating to reconstruction or the retrofit of pre-existing buildings for improved seismic resistance.
4- Provide recommendations for construction practitioners in the various strategies of disaster management systems, ethical and construction practices, enhancement of pre-existing buildings, insurance plans, and the role of local government bodies relevant to seismic regulations in Tehran.

1.5. Outline and Structure of Thesis

This thesis has been structured into three parts containing five chapters. Part one is comprised of chapters one and two which present the background and theoretical framework of the study and provides a review of the literature. Part two consists of chapters three and four which introduce the research design, research methodology and interpretations of the research findings. Part three is comprised of chapter five which summarizes the principal findings, offers a conclusion to the study and provides recommendations for future studies. The chapters outlined are as follows.

1.5.1. Chapter 1: Introduction

The study begins with a brief overview of disaster impacts and management processes. The introduction proposes the background of the research encompassing the problem statement, significance of the study, personal motivation, research objectives, and research questions.

1.5.2. Chapter 2: Literature Review

Chapter two provides a theoretical framework for the study along with a comprehensive literature review of disaster risk reduction strategies and the management of related issues. It defines key concepts related to disaster management models including definitions of disaster, hazard, and vulnerability. This chapter also characterizes the different phases, activities, components, and approaches to disaster management and risk mitigation cycles. In addition, a discussion and review of disaster risks in an urban built up environment are presented, and the roles of construction practitioners, governing bodies and landlords in relation to risk reduction are studied. A review of the disaster management methods of Tehran shall also be conducted to evaluate the degree of effective risk planning in the region.

1.5.3. Chapter 3: Research Design and Methodology

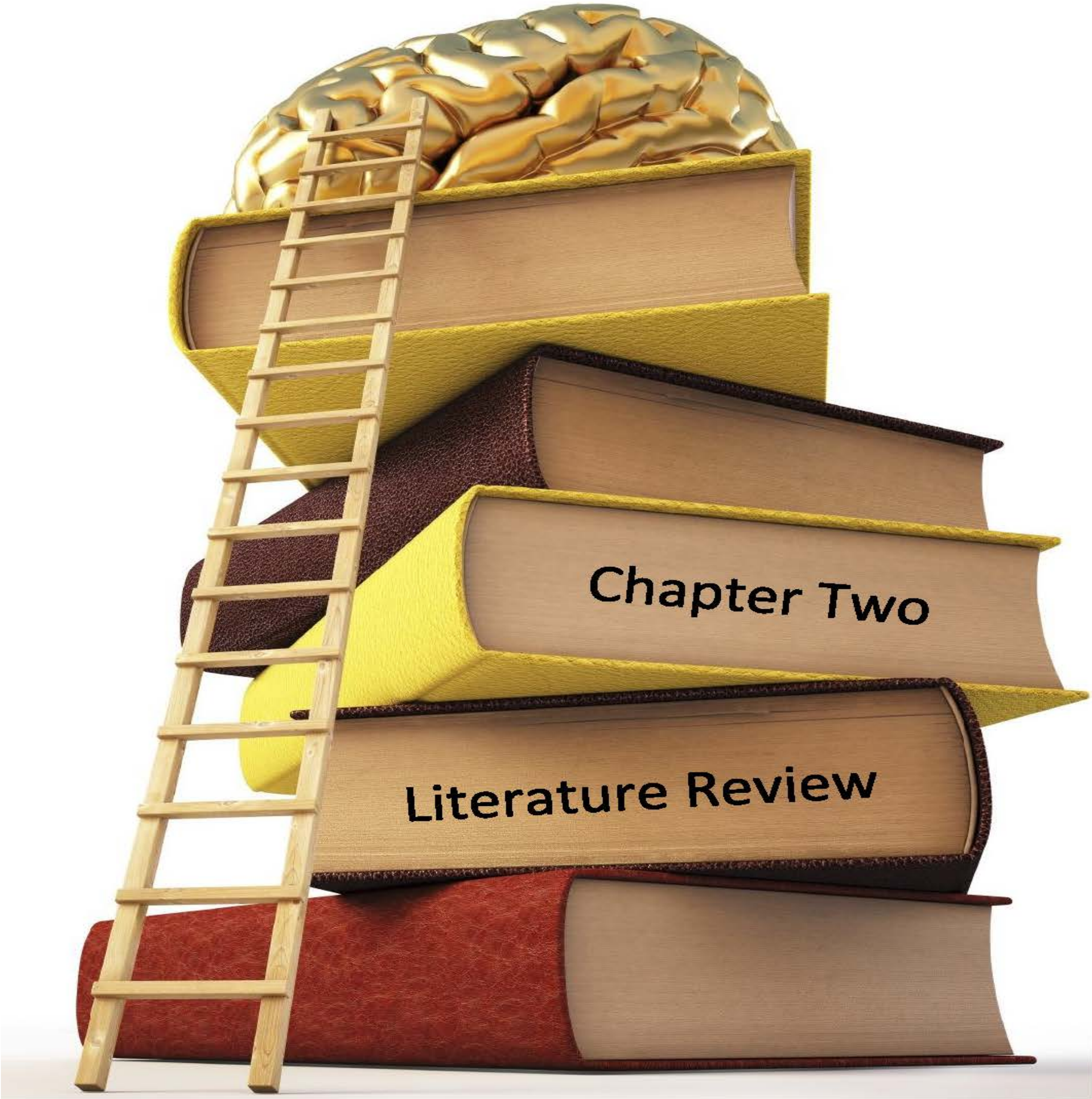
Chapter three serves to clarify the research methodology utilized in this study. It defines the research design and processes, data collection techniques for either primary or secondary data, sampling methods and data analysis methods. Details of the structured questionnaire for quantitative data gathering and semi-structured interviews for qualitative data collection are presented in this chapter.

1.5.4. Chapter 4: Data Analysis and Plan Results

Chapter four tenders the analysis, discussion and exploration of the assembled data. Primary data including survey questionnaire and interview data is analysed and compared against secondary data to determine in what manner Tehran's construction practitioners participate in earthquake disaster risk reduction practices.

1.5.5. Chapter 5: Conclusion and Recommendations

Chapter five presents the key findings obtained by this research and provides recommendations for the improvement of Tehran's construction industry policies, practices, and standards. Furthermore, research limitations and suggestions for future research determinations and offers recommendations for further studies relevant to this subject matter.


Chapter Two
Literature Review

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Humans spend their lives in direct contact with natural processes of the earth; some of which prove harmful to the environment and its inhabitants. Therefore, it is necessary to investigate the methods of coping with such hazards. During the last century, efforts have been made by the global community to develop our knowledge of strategies for the efficient management of natural disasters. The primary focus of this chapter is to develop an understanding of disaster risk and provide insight into disaster management methods. One method of coping with natural disasters is by enhancing buildings and infrastructures in order to withstand the effects of such events; thus, understanding the role of construction engineers in this effort is of critical importance and shall be thoroughly explored in this chapter.

This chapter commences with a discussion of the controversies surrounding definitions of key disaster-related terms and concepts. Disaster, hazard and vulnerability will be defined. The literature will review disaster risk reduction as well as risk management policies in addition to a discussion of the various phases, activities, and components of disaster management. Risk management shall be presented as a sequential process encompassing risk identification, risk analysis, risk reaction and risk monitoring.

This chapter shall review the disaster risk of an urban area and the various inherent vulnerabilities which built environments present. The significant roles played by construction engineers in the reduction of disaster risk will be discussed. Two perspectives relating to disaster management and risk reduction shall be explored; the first perspective is the role of local government and municipalities who have direct control over public works and social services, and who possess direct responsibility towards disaster management of urban areas. The second perspective being the role of construction practitioners and their contributions towards both pre-disaster related activity phases such as the design and construction of earthquake resistant buildings, and the post-disaster activity phases such as recovery and reconstruction. Ultimately, previous investigations which have been conduction by seismic professionals into the past seismic events in Tehran shall be examined to assess the accuracy of their findings.

2.2. Disaster

Over time various scholars have offered different definitions of disaster. Researchers such as Picou and Martin (2006), and Pyles (2007) have focused on the hazardous events of disaster and their subsequent damage to property and human life. Other researchers such as Coppola (2007) explain disaster not only in terms of the size, origin, nature and other physical aspects of the incident but also the circumstances which lead to the occurrence of such an event. The components of disasters include "*loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets*" (Ismail, Majid, and Roosli, 2014, p.3), environmental degradation, economic and social disruption and loss of public services (UNISDR, 2016).

The United Nation Office for Disaster Risk Reduction (UNISDR) also explains that disasters are often derived from the combination of (1) hazard exposure, (2) vulnerability and (3) insufficient means to mitigate or manage adverse consequences. In this interpretation, there are two main concepts related to disaster; (1) hazard which may develop into a disaster whenever the conditions of vulnerability and insufficient capacity to manage the hazard are present; (2) vulnerability which "*is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt*." (Adger, 2006, p.268). The degree of vulnerability in an earthquake hazard depends on the capacity and resilience of humans in coping with the hazard facing them (Norris et al., 2005), population growth and rapid unplanned urbanization (e.g., Ali et al., 2015; Zolfaghari, 2006), the deficit of policies aimed towards the reform of flawed construction practices and the poor planning of land usage due to the rapid growth of urban areas (Ali et al., 2015).

Khan et al. (2005) take into consideration certain economic factors which may also influence the level of vulnerability and state that high-income nations are less vulnerable to disasters than low-income nations, owing to the benefits of proactive policies which high-income nations are able to implement in anticipation of future disaster events. Hence, it can be concluded that "*peoples living in develop countries are less vulnerable in comparison to those living in developing countries*" (Smith, 2004, p.12). Kahn et al. (2005) argue that government corruption can contributes to a lack of building code enforcement, poor quality of infrastructure and neglect towards proper urban zoning practices, thus further increasing levels of vulnerability. Previous studies on disaster vulnerability have often focused upon identifying specific social groups that are highly vulnerable to hazard events. Some research highlights the vulnerability of children (La Greca et al., 2013), while some other research stresses the vulnerability of the elderly (Parker et al., 2015; O'Donnell and Forbes, 2016). Wisner et al. (2003) believe that poverty affects the ability of the people to cope with the impacts of a disaster, for instance, the ability to obtain life insurance may reduce vulnerability after the occurrence of a disaster.

Disasters are classified into two categories; those which occur naturally and those who are human-made. Natural disasters are events which occur as a result of natural forces and may be described as an act of God. The cause of natural disaster may be any one or combination of the events as described by Saltbones (2006) which include; (1) geophysical factors such as earthquake, (2) meteorological factors such as hurricanes, (3) hydrological factors such flooding, and (4) climatological factors such as extreme temperature.

Earthquakes are amongst the most dangerous types of natural hazard, in which the sudden release of potential energy in the earth's crust causes a measurable vibration of the earth's surface (Wen, Hu, and Hu, 2002). Earthquakes are a very specific type of natural hazard as they are relatively scarce in comparison to other natural hazards, however, when earthquakes do occur, the destruction and suffering may be immense (Press, 1984, cited in, Bozorgnia and Bertero, 2006, p.13). Bozorgnia and Bertero (2006) illustrate three potential major factors which may generate a severe earthquake disaster. Those factors are; 1) severity of the earthquake ground motion such as rock depth, soil condition, earthquake magnitude, and source-to-site distance, 2) the scale and distribution of the population and economic developments, and 3) the level of earthquake preparedness such as earthquake risk mitigation plans.

2.3. Disaster Management: Components, and Approaches

Lettieri et al. (2009) state that the definition of disaster management can apply to different aspects such as "*administrative decisions, the actors of technology, politics, or operational activity*" (p.117). These ideas apply to the stages of the disaster at different levels. Alexander (2000) highlights that disaster management must implement necessary operations such as mitigation, recovery, response, and preparedness. Preparedness and mitigation phases occur before the disaster, while the recovery and response phases occur after the disaster. It is important to consider two other factors before, during and after disaster occurrences; 1) components (disaster risk reduction and disaster risk management), and 2) approaches (proactive and reactive). Figure 2-1 illustrates these factors within their respective time of fulfilment. The following sections are dedicated to explaining the above elements in detail.

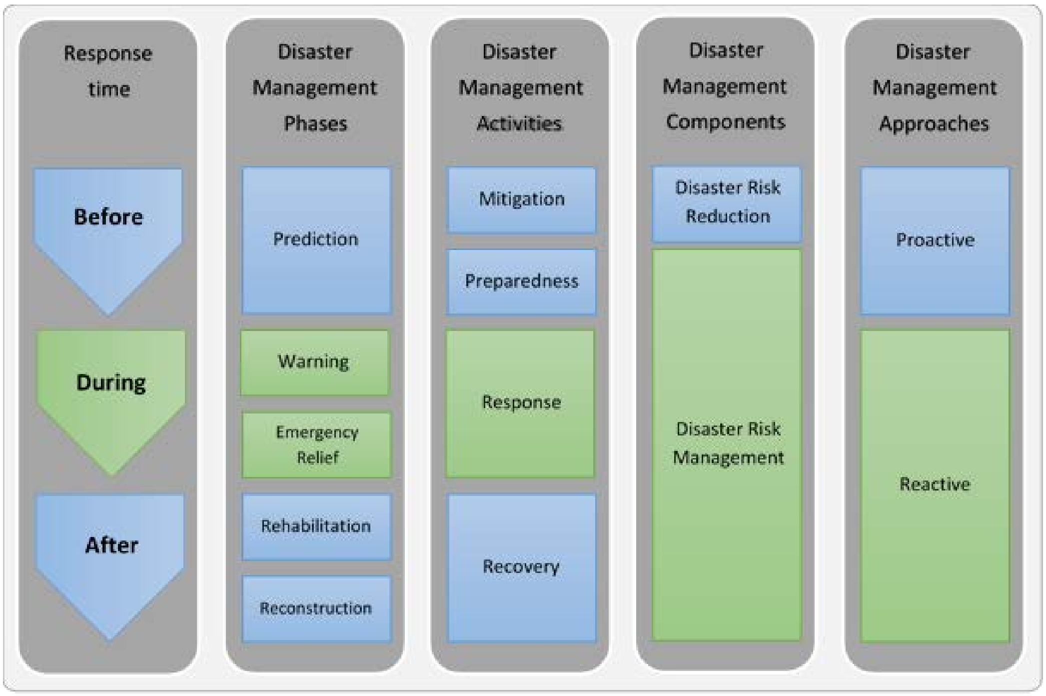


Figure 2-1: Disaster management: phases, activities, components, and approaches
(Moe and Pathranarakul, 2006, p.401)

2.3.1. Disaster Management Components

2.3.1.1. Disaster Risk Reduction

As the threat of disasters continues to increase affecting more people each year, the importance of international debates regarding the subject of disaster risk reduction becomes more vital than ever before. The necessity for a true commitment towards disaster risk reduction is made evident by the number of major natural disasters in the 21st century. These catastrophes provide strong motivation for scientists and professionals to engage in the research of solutions for disaster loss reduction.

A critical step towards hazard prevention and thus the prevention of a disaster event is to reduce the risk; these efforts are commonly referred to as Disaster Risk Reduction. Disaster risk reduction relates to both analysis of the concept, as well as the practice of minimizing disaster risks. Hence, disaster risk reduction encompasses both the identification of disaster risk (perception and evaluation of risk) and the management of risk (selection of the most appropriate method for risk management such as risk transfer, risk avoidance, risk reduction and risk acceptance) (Winch, 2009). On the 26th of December 2004, the Indian Ocean Earthquake and Tsunami refocused the world's attention upon the impacts of disaster and the reduction of disaster risk. A few weeks after this catastrophic event, in January 2005, a global conference was held in Japan (Kobe-Hyogo) in an attempt to develop strategies and policies focusing upon disaster risk reduction. The main focus of this conference was to decrease the exposure and vulnerability of the people, society, economy and built environment thereby increasing the quality of life (IPCC, 2012; Birkmann and Von Teichman, 2010).

The United Nation Office for Disaster Risk Reduction (UNISDR) presents a comprehensive definition of disaster risk reduction and believes that vulnerability along with disaster risk reduction plays a major role in sustainable development. UNISDR highlights two main components in the definition; (1) Disaster Risk Reduction and (2) Disaster Management. Disaster risk reduction is defined as the minimization of all risks which may contribute to and cause hazardous events. Disaster management, on the other hand, is related to the oversight and efforts made to reduce the impacts of a catastrophe. A common misunderstanding of the concept of disaster is the misconception that hazards are equal to disasters, for instance, earthquakes, storms, cyclones, and floors are often considered as natural disasters, however, these destructive hazards do not necessarily always result in disaster. When a hazard occurs in a vulnerable area, there is an increased high-risk potential that the hazard may develop into a disaster. As a concept, risk is typically regarded as the probable occurrence of hazardous activity and the consequences of the event (ISO, 2002), hence, both factor should be considered in disaster risk reduction.

Disaster risk is a complex subject including the two related concepts of hazard and vulnerability. In the context of natural disasters, due attention must be provided towards a vulnerability conscious approach rather than simply a hazard conscious approach. In other words, if the goal is to achieve a safer world the primary step in the disaster risk reduction process should be to shift the focus away from hazard control and instead focus on the assessment of present risks and vulnerabilities.

2.3.1.2. Disaster Risk Management

In consideration of the previously discussed literature, it can be deduced that disaster risk management consists of the following two components: (1) choice of action, and (2) outcome. It is important to understand that any choice of action may ultimately expose people to risk, it is therefore clear that anybody may be exposed to risk and that no person is guaranteed absolute safety. The scale of potential risk may also differ from person to person and case to case. Furthermore, the person facing the risk may not be the person deciding upon the choice of action, hence, in addition to the choice of action the outcome of the chosen decision is of high consequence. The uncertainty of results due to the interrelation of certain variables such as time and magnitude of risk prove the complexity of disaster risk management as a concept. Hillson (2002) states that opportunities and positive outcomes can be achieved through the effective management of events even though the risk may result in negative consequences. Olsson (2007) argues that a comprehensive and practical risk management procedure should address all issues including any risks and uncertainties.

Due to the inherent challenges and complexities of disaster risk management, researchers offer varying thoughts on the risk management process. Thompson and Perry (1992), for instance, separate disaster risk management into two phases comprised of risk assessment and risk management. Ferrier and Haque (2003) believe that the risk management process consists of three main steps; (1) identification of hazards that can lead to disasters, (2) estimation of the risks derived from the dangers, and (3) deliberation of the possible consequences. Winch (2009) merges these two ideas and classifies disaster risk management as; (1) disaster risk identification, (2) disaster risk assessment and analysis, (3) disaster risk response and reaction, and (4) disaster risk monitoring.

2.3.1.2.1. Disaster Risk Identification

The initial phase of disaster risk management is known as Disaster Risk Identification. It is also the most significant step in the disaster risk management process since unless the risk has first been identified no reaction can be taken against it (Forbes et al., 2008, p.1142). Hence, risk identification is essential to determine an appropriate response to the risk. Categorization of risk, discovery and its identification are the main objectives of risk identification. The procedure of risk identification can be exercised either through documentation review or through information gathering methods such as brainstorming and interviews, the risk breakdown structure (RBS), checklist analysis, assumption analysis and diagramming methods (Forbes et al., 2008; Project Management Institute PMI, 2008).

2.3.1.2.2. Disaster Risk Assessment

Obtaining a thorough understanding of disaster risk identification is the first stage in the disaster risk management process. After which, a step known as Disaster Risk Assessment or Disaster Risk Analysis is crucial for both policy formation and action planning towards the reduction of disaster risk. The main focus of risk assessment is to evaluate and analyse the risk in detail (Kern et al., 2012). The risk evaluation process is often a matter of weighing statistical probabilities against experimental and subjective data.

An examination of the various aspects of disaster risk management, as conducted by INSDR (2016) highlights the fundamental activities of the risk evaluation process. These activities include; the characterization of hazards such as frequency, location, probability and intensity, and the analysis of vulnerability and exposure including environmental dimensions, health effects, social aspects, physical aspects and economic aspects. Three key components of disaster risk assessment are; (1) identifying elements at risk, (2) hazard occurrence probability, and (3) vulnerability of the items at risk (Alexander, 2000; Coburn and Kuran, 1991).

2.3.1.2.3. Disaster Risk Response

In addition to risk identification and assessment, there must be an action plan in order to manage risk effectively. Risk response is usually focused upon selecting and implementing cost-effective actions which make the risks acceptable. In fact, risk response refers to the process of selecting the best possible options for managing previously identified risks. The risk response process can be divided into four distinct strategies: (1) risk transfer, (2) risk avoidance, (3) risk reduction, and (4) risk acceptance (Hillson, 2002. p. 238; Beddington, 2012, p. 76).

Risk Transfer: Risk transfer tends to '*shift the financial consequences of particular risks from one party to another whereby a household, community, or enterprise*.' (UNISDR, 2016)
A practical example of risk transfer and in the context of earthquakes is the purchase of a building insurance policy by which a specified risk of loss is passed on from the victim to the insurer.

Risk Avoidance: Risk avoidance seeks to alter circumstances surrounding the risk in an attempt to negate the risk. Beddington (2012) proposes migration from high-risk seismic zones as an option for risk avoidance. He believes that although migration enables the avoidance of risk, it has the potential to harm people in other ways.

Risk Reduction: The primary concern of disaster risk reduction is exposure to hazards and the vulnerabilities of people, societies, economies and built environments, all of which affect the quality of life (IPCC, 2012; Birkmann and Von Teichman, 2010). A practical example of risk mitigation, in the context of earthquakes and their impacts, is the improvement of building code compliance and standards thereby enabling the delivery of earthquake-proof buildings which serve to reduce the damages incurred during an earthquake (Government of Japan, 2005).

Risk Acceptance: Beddington (2012) states that risk acceptance is an informed decision which permits risk when there is either no better choice or when the costs of action outweigh the benefits. An example of risk acceptance in the context of a seismic event is the planned reconstruction of damaged or collapsed buildings in order to improve earthquake resistance for the future.

2.3.1.2.4. Disaster Risk Monitoring

The final step of the disaster risk reduction process is Risk Monitoring. The identification of new potential risks is a motivating factor in the risk monitoring process which can also serve to guarantee the effectiveness of the risk management process (British Standard, 2001). Hence, risk monitoring can assist in the mitigation of loss exposure. In the context of earthquake risk, risk monitoring often manifests itself in the form of building codes to reduce the likelihood of collapse (Olson and Dash Wu, 2010).

2.4. Disaster Management and Disaster Management Cycle

A number of scientists propose various models and phases for disaster management procedures (Alexander, 1993; Asian Disaster Risk Centre, 2005; Shaluf, 2008; Amin, Cox, and Goldstein, 2008). Due to the diversity of policies and legal systems in countries across the globe, there are many different proposals for disaster management systems. However, the timely and efficient management of such systems is the main focus of each nation. Lixin et al. (2012) compare the disaster management systems of countries such as America, China, Japan, and they conclude that each has differentiating systems of disaster management. The reason for this variation is that each nation practices different forms of organizational structure, for instance, they highlight that "*organizational structure in America and Japan are integrated, while in China is decentralized*." (Lixin et al., 2012, p.303). Another reason for this variety of disaster management systems are the distinct legislations which countries practice, for example, "*The disaster management legal systems in America and Japan are properly constituted*." (Lixin et al., 2012, p.303), whereas in China, the legal framework for disaster management has yet to be fully implemented.

Disaster management cycles transpire due to the repeated occurrence of disaster events and can be classified into four phases comprised of response, mitigation, recovery and preparedness. The preparedness and mitigation phases occur prior the disaster event whereas the recovery and response phases occur after the disaster event (Figure 2-2). Altay and Green (2006) illustrate through their research review that scientists have not paid equal attention to all of these phases and state that 44 percent of previous articles focus upon the mitigation phase whilst only 11 percent focus upon the recovery phase (p.480).

Figure 2-2: Disaster management cycle (Alexander, 2000)

Disaster Mitigation: The premeditated minimization of a disaster's impacts upon social systems and ecosystems is known as Disaster Mitigation. Disaster mitigation is classified into two categories including (1) structural mitigation and (2) non-structural mitigation (Hidayat and Egbu, 2010). Structural mitigations, in the context of seismic hazards, are engineering solutions for the reinforcement of buildings and the retrofit of built environments, while non-structural mitigations concentrate on the identification of vulnerable areas and the manipulation of new development towards increased safety through the use of methods such as land-use planning, insurance, etc. (Lyles, Berke, and Smith, 2013; Lettieri, Masella, and Radaelli, 2009; Bosher, 2008;

Simpson, 2002). It is widely accepted that non-structural mitigation activities have the potential to significantly stimulate disaster risk reduction.

Disaster Preparedness: Badruddin (2012), and Perry and Lindell (2003) emphasize that the training and education provided to the responders of disaster is a critical component of disaster preparedness and is often conducted by the public in coordination with local government in anticipation of future events. Disaster preparedness within the construction industry may include planning, training, and exercise to advance the capability of specialists operating within the disciplines of construction practice and emergency management in order to increase their capacity to withstand the impacts of disaster events.

Disaster Response: Fitzgerald (1996) states that the people who perform the immediate response during and after a catastrophe are known as responders. These responders may include skilled staff, rescue teams and international relief organizations which provide evacuation services, the distribution of essential resources and the care of victims (Bertrand and Lajtha, 2002). "*The goal of the responder is to save lives, minimize property damage and enhance the beginning of recovery from the incident*." (Shaluf, 2008, p.123). Disaster response in relation to construction professionals refers to providing appropriate rescue plans and emergency sheltering plans to protect the victims after the occurrence of a catastrophe.

Disaster Recovery: The duration of the response phase is often less than that of the recovery phase. Miles and Chang (2006) highlight that the primary purpose of the recovery phase is to restore the environmental, social and other conditions to levels which they had been prior to a disaster (Kreps, 1983). The recovery phase is a major element of the disaster cycle and serves not only for re-planning and reconstruction but also for the preparedness and mitigation of potential future hazards.

Although the above classifications are valuable and remain widely used, it is important to acknowledge that the various phases of the disaster management cycle overlap and are not step-by-step processes. The disaster management cycle, as presented by the Federal Emergency Management Agency (FEMA, 2006) and supported by some scientists, is an open-ended model with an overlap between phases. Both FEMA and the supporting scientists believe that recovery activities may also function as mitigation activities in anticipation of future events (Shaw, 2006; Goyet, 2008; Labadie, 2008).

2.5. Earthquake Disaster Management in Urban Areas and Built Environment

Urban areas are facing an array of natural hazards which may have the potential to lead to a disaster. The scale of risk in an urban area is dependent upon the vulnerability of the area and its capacity to cope with the impacts of a hazard. A lack of appropriate infrastructure and public services along with improper land-use management are examples of problems which may negatively affect the scale of risk in an urban area. Furthermore, the number and density of the urban population are directly linked to the degree of disaster risk.

Swiss Re in the article “Mind the risk” (2014) reports upon the top-ten cities which are threatened by earthquake events. As illustrated in Table 2-1, this report presents the two most important parameters for determining the earthquake threat posed upon cities;

(1) disaster impacts upon communities by reflecting the absolute number of people who potentially affected;

(2) and disaster impacts on economies by considering the total value of lost working days.

An important item in this list, pertinent to this study, is the presence of the city of Tehran amongst the world’s top ten cities under threat by earthquakes.

Table 2-1: Top ten city rankings by analysis for all aggregated perils (Swiss Re, 2014)

METRO AREA	PEOPLE POTENTIALLY AFFECTED MILION	METRO AREA	VALUE OF WORKING DAYS LOST DAYS	METRO AREA	VALUE OF WORKING DAYS LOST RELATIVE TO NATIONAL ECONOMY DAYS
Tokyo-Yokohama (JPN)	57.1	Tokyo-Yokohama (JPN)	4.50	Manila (PHL)	1.95
Manila (PHL)	34.6	Osaka-Kobe (JPN)	2.71	Amsterdam-Rotterdam (NLD)	1.31
Pearl River Delta (CHN)	34.5	Nagoya (JPN)	2.69	Tokyo-Yokohama (JPN)	1.29
Osaka- Kobe (JPN)	32.1	Pearl River Delta (CHN)	1.78	San Jose (CRI)	1.26
Jakarta (IND)	27.7	Amsterdam-Rotterdam (NLD)	0.96	Guayaquil (ECU)	1.20
Nagoya (JPN)	22.9	Los Angeles (USA)	0.93	Taipei (TWN)	1.02
Kolkata (IND)	17.9	New York-Newark (USA)	0.62	Ndjamena (TCL)	1.00
Shanghai (CHN)	16.7	San Francisco (USA)	0.47	Nagoya (JPN)	0.97
Los Angles (USA)	16.4	Paris (FRA)	0.46	Tainan-Kaohsiung (TWN)	0.90
Tehran (IRN)	15.6	Taipei (TWN)	0.39	Lima (PER)	0.90

It is evident that the economic impacts of lost working days are greater in developed countries such as the United States, China, Japan, France and the Netherlands than those in developing countries. The main factor for this is the larger scale of economic and social activities operating within the developed countries in comparison to the developing countries. Due to the high value of assets and large populations in megacities, which are cities with more ten million inhabitants, they are more exposed to the vulnerabilities of the hazard. Regardless of whether being located within a developed or developing country, megacities also suffer from economic vulnerability. The occurrence of hazards in megacities often results in; increased levels of mortality and morbidity; the suspension of political frameworks; a disruption of trade balance, supply chains, and production; the conception of economic crises (Fernandez et al., n.d). Therefore, due to the presence of the above factors in complex urban areas, greater attention is required when evaluating an appropriate disaster management process.

In response to this devastating reality, the author pays greater attention to earthquake management in relation to construction practices in Tehran and its built environment. "*Buildings and lifeline systems are termed the built environment*" (Erdikt et al., 2003). Scholars believe that a key element of risk reduction in disaster management is the performance of thorough risk assessments on the vulnerabilities of built environments pertaining to earthquakes (e.g., Wenzel, 2006; Hayashi and Kobayashi, 2006). The number of residents inhabiting informal settlements is an important aspect of disaster risk reduction in urban areas (Wenzel, 2006). Many other parameters such as the construction of inappropriate habitations, rapid population growth, improper land-use planning, and the deficiencies of local governments are important factors to consider when performing a risk assessment (Zolfaghari, 2006; Ghafory-Ashtiany cited in UN, 2004). Some of the most common problems which contribute to the heightened vulnerability of a built environment are the poor quality of construction along with inadequate infrastructures and public services which serve to increase disaster risk substantially (Amini Hosseini and Jafari, 2007; Hosseini and Amini Hosseini, 2008). Furthermore, in order to provide a dependable representation of risk assessment in threatened cities, accurate information is required on all households, buildings, infrastructures, neighbourhoods, and enterprises within the city. Hence, the role of local government professionals is essential for compiling a detailed database in order to provide the necessary information to conduct a reliable risk assessment for future events (UN, 2004).

2.6. Disaster Management Cycle in Tehran

The disaster management cycle in Tehran can be categorized into four phases including mitigation, preparedness, response and recovery or reconstruction. It is important to study the disaster management cycle in Tehran to understand the relative phases and the role of construction professionals throughout the various disaster management stages. The role of construction professionals in the development of earthquake-proof buildings is a vital component of the mitigation phase and the main focus of this study.

2.6.1. Mitigation and Prevention Phase

Prevention is the first step of the cycle of disaster management. Results of the study conducted by Testushi Kurita into the 1995 Kobe Earthquake indicate that investment to improve buildings, infrastructures, and lifelines in the mitigation phase could have saved the lives of up to 92% of the earthquake victims, whilst the maximum percentage of victims able to be saved through better implementation of the preparedness phase was only 8% (cited in UN, 2004).

Vaziri et al. (2010) conducted a case study into disaster management in Tehran and the potentiality of building damages resulting from an earthquake. They attempt to answer questions such as; (1) whether the money should be invested in the pre-earthquake mitigation process or whether the investment should be postponed until the post-earthquake reconstruction and the rebuilding of damaged buildings; and (2) which buildings should be retrofitted and how, and which buildings should be reconstructed and how. Through their case study they discovered that: (1) many buildings which are destroyed in an earthquake could not be immediately reconstructed due to the non-availability of funds, and (2) buildings should be either reconstructed or retrofitted based upon the appropriate structural types and seismic design levels with an intent to achieve both low vulnerability and low cost simultaneously.

2.6.2. Preparedness Phase

Preparedness is the next phase of the disaster management cycle. The Japanese model for preparedness planning promotes a system of education which enables people to understand the importance of self-protection and mutual-assistance to reduce the government's initiative (Mukunoki, 1988 cited in Walls and Mujoo, 2002). According to the study conducted by Hosseini and Amini Hosseini (2008) in Tehran, there are two essential components of the preparedness phase which have influential roles in risk reduction. The first component is the promotion of public awareness and education regarding earthquake hazards. Hosseini and Amini Hosseini (2008) confirm the importance of the role played by construction practitioners in the preparedness phase and the importance of their awareness regarding earthquake disaster. The training of engineers to improve their knowledge of earthquake and their skills to assess levels of vulnerability is of critical value to the preparedness phase of Tehran's disaster management cycle. Construction practitioners should also be aware of the system and structure of disaster preparedness and the duties to be managed by each organization engaged in disaster management. The second component of the preparedness phase is to establish a culture of awareness and self-protection within communities through the availability of educational information and the implementation of proactive safety measures within the home. Thus, public community preparedness is a key component in reducing the impacts and losses sustained during an earthquake.

2.6.3. Response Phase

The improvement of emergency response provisions and the establishment of a formal emergency response plan are the two basic actions of the response phase in the earthquake disaster management cycle of Tehran (Mehdian et al., 2004). Hosseini and Amini Hosseini argue that several aspects of emergency response should be considered in the master plan of the city. They identify the aspects of emergency response as; "(1) *emergency response command*; (2) *rescue, relief, and medical treatment*; (3) *evacuation*; (4) *emergency traffic*; and (5) *lifelines*" (Hosseini and Amini Hosseini, 2008, p.5).

Construction practitioners can impact the emergency response plan both directly and indirectly. Their direct impact refers to, for instance, the implementation of appropriate evacuation plans within earthquake-proof buildings and the utilization of fire proof materials in the construction of such buildings. Their direct impact may also refer to the design of appropriate master plans to ensure efficient emergency vehicle access and victim sheltering provisions after an earthquake. Their indirect impact refers to, for instance, community-based activities which help to provide the necessary resources for search and rescue operations after an earthquake. Thus, resource and responsibility allocation, clarification of accountability, and public participation are the most important aspects of engineers' involvement in the response stage of the disaster management cycle (Wisner and Adams, 2002).

Although a plan has been developed by the Tehran Disaster Mitigation and Management Organisation (TDMMO) to mobilize all the resources of the country in the event of a disaster, investigations indicate that there is a resource limitation hindering their ability to cope with a large event, in addition to the issue that municipal staff have not been properly trained in post-disaster operations (Ghafory-Ashtiany, 1999).

2.6.4. Recovery and Reconstruction Phase

The final phase of the disaster management cycle is recovery. Recovery consists of the establishment and practice of reconstruction and rehabilitation activities. Maheri (1998 cited in Ghafory-Ashtiany, 1999) highlights that approximately 500km west of the neighbouring city of Kerman lies an area of Ghaen City named Golbaf, where the implementation of building reconstruction was able to reduce the fatality rate significantly from 1500 deaths during a pre-reconstruction earthquake in 1981 to 5 deaths during a post-reconstruction earthquake in 1991, despite the fact that the latter earthquake had occurred during the night when a majority of the residents were asleep in their homes which would typically result in a higher number of fatalities.

Ghafory-Ashtiany (1999) believes that there are five essential principles which should be considered by construction professionals during the reconstruction stage. These five principles consist of; (1) Site selection, which refers to the selection of appropriate locations for the construction of new buildings based on local geology, cultural aspects, seismic tectonic, socioeconomic, seismicity, and geotechnics; (2) Seismic design, which refers to the implementation of the latest earthquake design codes and standards for the construction of all new building structures; (3) Construction material, ensuring that all building materials utilized in new construction is in compliance with high quality and standards required in earthquake-proof structures; (4) Workmanship, ensuring that only licensed companies are permitted to execute the construction with qualified staff and under the supervision of engineers; (5) Quality and monitoring, ensuring that qualified engineers conduct inspections on the construction based on seismic standards and codes, whom regularly update their knowledge of seismic criteria. Hosseini and Amini Hosseini (2008, pp.7-8) explain that reconstruction within the disaster management master plan of Tehran can be categorized into the following five stages:

- **Stage 1:** Setting up a framework for urban reconstruction within one week from the time of the event.

- **Stage 2**: The Establishment of basic policies for urban reconstruction within one month from the date of the event.
- **Stage 3**: The Establishment of a core plan for urban reconstruction within six months from the date of the event.
- **Stage 4**: Conforming the plan and creating a practical program for reconstruction within one year of the disaster.
- **Stage 5**: Implementation of urban reconstruction projects based on the program and starting reconstruction works which may take several years.

2.7. Disaster Management Plan in Tehran

As a result of the development plan directed by the Tehran Disaster Mitigation & Management Organization (TDMMO), the disaster management plan of Tehran has been significantly strengthened in comparison to prior years (Government of Iran, 1979, 1989). However, despite this development, the occurrence of an extreme seismic hazard would undoubtedly have a severe impact on the city and its inhabitants. A primary reason as to why the disaster management plan of Tehran still faces many problems and obstruction is that the disaster management issues have yet to be fully resolved or realized. A major issue with the disaster management plan of Tehran is that their model is focused solely upon the post-disaster response phase (Ghafory-Ashtiany et al., 2000). Although post-disaster response planning is a critical component of disaster management, the sole emphasis on the post-disaster response is only capable of reducing a small proportion of risk and creates substantial policy gaps which can increase vulnerability (Wenzel, 2006). Therefore, in order to better protect assets, reduce losses and fatalities, and to ensure the reduction of damages in a mega-city such as Tehran, attention must be given towards establishing a cost-effective mitigation phase within the greater disaster management plan.

2.7.1. Earthquake Disaster Management Plan in Tehran

It is reasonable to surmise that without a prior understanding of earthquake risk it would not be possible to provide an appropriate earthquake disaster management plan. The most efficient tool which can be utilized to assess earthquake risk is to conduct an estimation of the potentiality of building collapse and human casualties against specific earthquake motions which have occurred in the area (Hayashi and Kobayashi, 2006). Another function of a disaster management plan is to evaluate the capacity of an earthquake's effects on an urban area. This evaluation should include emergency response capabilities, preparedness to a hazard, physical vulnerability and public awareness. Amin Hosseini et al. (2013) researched the socioeconomic aspects of disaster management plan in Tehran. They conclude in their research that despite some efforts such as an assessment of the cost-benefit relationship of retrofitting vulnerable structures and the renovation of Tehran's antiquated urban fabric, the existing laws and regulations pay little attention to socioeconomics due to poor management and an unbalanced hierarchy of power within the city; all of which must be reformed and improved throughout the districts of Tehran (Amin Hosseini et al., 2013, pp. 520-521). Ghafory-Ashtiany et al. (2000) reported that "*Iran's achievement in earthquake hazard related risk mitigation has been a successful experience from1990 till 2000*" (p.2380).

The city of Tehran has been devastated on at least two occasions in recorded history by major earthquakes greater than 7.0 Richter, as displayed in Table 2-2, with the interval between these two major events being approximately 150-200 years as studied by Ambraseys and Mallvile (1982). They conclude that Tehran should be in anticipation of another major earthquake greater than 7.0 Richter in the proximate future. Hence, it is essential for Tehran to implement a comprehensive earthquake disaster management plan for the pre-emptive management of such an event. Poor construction practices and a general lack of engineering knowledge regarding destructive earthquakes are the major issues which must be suitably addressed in a disaster management plan.

Table 2-2. Destructive earthquakes in proximity of Tehran (Ambraseys and Mellvile, 1982)

Year	Approx. Magnitude in Richter	Years from the previous event
400 BC	7.6	0
743	7.2	1143
855	7.1	112
958	7.7	94
1177	7.2	219
1665	6.5	488
1815	8.0	150
1830	7.1	15

2.7.2. Issues Related to Earthquake Disaster Management Plan in Tehran

The Tehran Disaster Mitigation and Management Organisation (TDMMO), who are affiliated with Tehran Municipalities, maintain formal responsibility for the management of all disasters including earthquake events within the Tehran region in coordination with several disaster management stakeholders to cover all phases of the disaster management cycle. They explain several problems relating to the earthquake disaster management plan as follows:

2.7.2.1. Disaster Management Organisation

The response phase is the only stage of the disaster management cycle over which the Tehran Disaster Mitigation and Management Organisation (TDMMO) bears actual responsibility while the other phases including monitoring, risk assessment, relief recovery and forecasting remain under the purview the other authorities. Hence, the lack of a clearly defined organizational structure is evident in regards to the implementation of risk reduction programs and the overall disaster management model of Tehran (Ghafory-Ashtiany, 2006). Furthermore, the highly centralized nature of Tehran’s disaster management system coupled with the authorities neglect of community-based organizations (CBOs) is another obstruction (Amini Hosseini et al., 2013, p.530). Mehdi et al. (2004) argue that Tehran Municipality should promote the involvement of CBOs and assist in the resurgence of their operations in order to protect the lives of local inhabitants and their assets from the damages and losses caused by the earthquake.

2.7.2.2. Building Laws and Regulations

Consequent to the study conducted into the Marmara earthquake (August 17, 1999) in Turkey, the report provided by the Istanbul Technical University (ITU, 1999) highlights that the main contributing factor to the major damages sustained by buildings was the disregard of Turkey’s strict building and earthquake safety codes (cited in Özerdem and Barakat, 2007, p.431). According to the report presented by the Seismic Safety Commission (2000), Turkey suffers from a lack of building code enforcement due mainly to the inadequacy of current legislation and longstanding construction practices. In contrast, the same report indicated that damages sustained during the earthquake events in Taiwan (September 21, 1999, ChiChi Earthquake) and in Greece (September 7, 1999, Athens Earthquake) were comparatively less than those of the Marmara earthquake. The main reason for this contrast is that the construction standards implemented in these cities over the prior 25 years were similar to those of the California Uniform

Building Code and the thus the majority of affected buildings were in compliance with the respective building codes (Seismic Safety Commission, 2000).

Due to the rapid growth of Tehran's urban area and in addition to the absence of land use regulations and the inadequate regulations enforced upon local construction, most buildings are constructed without compliance to seismic codes which is especially true in the central and older parts of the city (Hosseini and Amini Hosseini, 2008). Furthermore, this lack of regulation creates an environment of disability in which construction engineers, local government, and developers are not empowered to provide adequate supervision during construction to ensure compliance with seismic codes. It is also evident that the current legislation and regulation pays little attention to the socioeconomic aspects of earthquakes, with the source of this neglect being the hierarchy of power within the upper governance of Iran (Amini Hosseini et al., 2013, p.520).

2.7.2.3. Emergency Plan and Rescue Operation

In any country where the inhabitants are faced with the genuine possibility of an earthquake in their daily lives, an effective civil defence system and the emergency plan has the potential to save countless lives. An earthquake warning system, which served as part of a larger emergency plan, saved many lives in the United States of America by causing the temporary shutdown of power plants, nuclear power facilities, and LPG distribution stations in the event of an earthquake (Kusky and Kusky, 2008). Another component of emergency planning is emergency sheltering programs including the appropriate selection of temporary shelter sites, types of structural shelters and temporary infrastructure requirements (Omidvar et al., 2013). The above factors of an emergency plan are only made possible through the involvement of qualified construction engineers in the relevant fields.

Emergency relief centres such as hospitals and fire stations must also be strengthened against seismic activity in such a manner that they remain operational after an earthquake (Ghafory-Ashtiany, 1999). Figure 2-3 illustrates the damages caused to a firefighting station during the Bam Earthquake of 2003 in Iran. The fire truck is completely destroyed before it can be used. (Amini Hosseini and Jafari, 2007).

Figure 2-3: Damages of the firefighting stations in Bam Earthquake 2003 (Amini Hosseini and Jafari, 2007)

Tehran is one of the largest cities not only within Iran but also in the Middle East. Consisting of 22 municipal districts, Tehran is a centre for culture, economics, industry, and politics and has rapidly developed into a densely populated metropolis. However, Tehran's emergency planning, which is essential for the welfare of any megacity, has been poorly endeavoured and faces a myriad of requirements and associated problems. Tehran's focus on the expansion of mid to high-rise buildings in the absence of proper lifelines and emergency planning is one factor which may catalyse the development of an earthquake hazard into a disaster event, both in terms of the immediate and delayed impacts of the event (Amini Hosseini and Jafari, 2007). Zolfaghari (2006) states that Tehran's continued construction of mid to high-rise buildings along narrow streets without any enforced setback creates a challenging scenario for rescue operations and relief efforts. Town planning professionals and municipal engineers are the major trustees for addressing these urban problems, enhancing the performance of community infrastructures, and satisfying the needs of the inhabitants.

2.7.2.4. Insufficient Funds and Insurance

The funds available for disaster management in Iran are insufficient when compared to the funding available to other countries such as Turkey. In Turkey, for instance, "*The World Bank* *agreed to finance a $US 1.8 billion reconstruction projects provided the Turkish government for development*” (Seismic Safety Commission, 2000, p.3) after the events of the 1999 Marmara Earthquake. Due to Iran’s lack of available funding and insurance policies to cover the impacts of an earthquake event, the necessary financial funding for reconstruction and rehabilitation, therefore, remains under the responsibility of the government. Ultimately, it will push the government to either divert funding from other development projects or request help from international donors in order to fund the recovery of the disaster area (Zolfaghari, 2006). Hence, the disaster risk management model of Tehran is in urgent need of public-private partnerships.

One of the best methods to minimize the impacts of natural hazards is to promote the culture of obtaining natural hazard insurance (Hosseini and Amini Hosseini, 2008). An insurance-based recovery plan assists the development of the private insurance sector by generating a source of revenue and providing financial support to the disaster victims. Therefore, the promotion of utilizing natural hazard insurance policies is a valuable component of risk reduction and should be considered as a priority in disaster management planning. However, this method is entirely ignored by the government, property owners and engineers in Tehran. In fact, “*insurance industries in Tehran are neither big and mature enough nor well accepted by people as an alternative for compensation*” (Zolfaghari, 2006, p.9). Meanwhile, in Turkey, it is mandatory that all building owners must obtain earthquake insurance, and the terms of the insurance are similar to those in the insurance policies of New Zealand which have a very successful model (Seismic Safety Commission, 2000).

2.7.2.5. Ethical Issues Related to Construction Practice

Ethical issues are one of the most significant problems within the global construction industry and also within the local construction industry of Tehran. Riihela and Vayrynen (1997) state that “*even one single saviour violation on ethical behaviour can damage the whole profession*” (cited in King et al., 2008, p.12). Transparency International (2005a; 2005b) believe that unethical practices within the construction industry lead to greater corruption than in any other sector of the global economy and reports upon numerous examples of corruption which have taken place within major international construction projects.

Despite several laws and regulations which have been approved by the disaster management system of Iran (Government of Iran, 1979, 1989), which remain far below international standards, the poor enforcement of codes and laws (Ghafory-Ashtiany, 2006) along with a lack of incentives to comply with regulations is clearly evident (Daftari cited in UN, 2004); all of which contributes to the vulnerability of buildings and increased risk. Zolfaghari (2006) purports that corruption and a lack of clear procedures regarding unethical behaviour are the primary reasons why construction engineers in Tehran often turn a blind eye to such regulations.

2.7.2.6. Social Participation

Although social participation is not the focus of this research, public awareness and community education can play a significant role in risk reduction. Nongovernmental organizations "NGOs" can support disaster management structures and participate in the implementation of regulations and community awareness. The law formulation mechanism is non-operational in Tehran, thereby restricting the possibility of NGO participation in disaster mitigation and prevention. Proprietors and tenants could, for example, utilize their influence by requesting municipalities and developers to provide all design documents such as the architectural, structural and rescue plan drawings whenever a property is sold or purchased. However, proprietors in Tehran do not currently hold sufficient influence to ensure that their potential investments or current assets are earthquake resistant due to the scarcity of earthquake insurance policies and the authority's insufficient management of building completion procedures.

2.8. Tehran Earthquake Management Plan: Construction Practice Policies

The majority of damage sustained during a seismic event is often caused by a variety of factors relating to construction practice. Patel describes these factors as "*the improper planning of cities and various infrastructure facilities, lack of site investigations and soil studies, improper structural planning and design, violation of specifications, poor quality control at construction works, and lack of coordination between [the engineers in various agencies]*" (2010. P.29). Hosseini and Amini Hosseini (2008) believe that optimal earthquake management planning should focus on proactive disaster prevention; they put forward some policies for earthquake disaster mitigation pertinent to the construction practice of Tehran which shall be outlined in the following sections.

2.8.1. Strengthening Existing Buildings

Investigations show that the majority of existing buildings in Tehran have the potential to sustain heavy damage from a strong earthquake (Mehdian et al., 2004). Ghafory-Ashtian states that the reasons are "*lack of code enforcement, changes to seismic hazard zoning, poor design standards and detailing, inadequate design, and poor supervision*" (cited in UN, 2004, p.3). Therefore, the strengthening of existing buildings is vital for the prevention of building collapse in the event of a strong earthquake (Wenzel, 2006).

The cost of reinforcement for existing buildings varies widely based on many factors such as the method of retrofitting, building type, building age, building usage, number of stories, and country of the project. In order to prepare the necessary plans for the retrofit of existing buildings within a city, it is essential first to identify which of the buildings are at greater risk. Meeting the requirements of reconstruction codes are often less expensive than the retrofit of existing buildings for the purposes of earthquake resistance (Moore, 2000). Murat Bursa conducted an investigation into the different types of investment which had been undertaken in Turkey between 1992 and 1999 in regards to either: (A) the reconstruction of new buildings, or (B) the strengthening of existing buildings (cited in UN, 2004). During his investigation, he discovered that for each 1 USD spent on the reconstruction of new buildings after an earthquake a value of 40 USD would be recovered, whereas for each 1 USD spent on the retrofit of existing buildings after an earthquake a value of only 8 USD could be recovered. Despite this information developers commonly prefer to invest in the retrofit of existing buildings rather than the reconstruction of new buildings.

In the city of Tehran, the practice of strengthening existing buildings would not be acceptable if the work is costly, technically unfeasible or socially inappropriate. The author's firm has engaged in the strengthening of several existing buildings in the private sector and discovered that both the private and public developers prefer to invest in the retrofit of existing buildings rather than reconstruction of new buildings after the collapse. Ghafory-Ashtiany (2006) recommends that the government should prioritize the allocation of special funds towards the strengthening of important public buildings such as schools, hospitals, and firefighting stations. Furthermore, insurance policies within the private sector are urgently needed which would enable proprietors to invest in the retrofit of existing buildings.

2.8.2. Improving Existing Urban Structures

Amini Hosseini and Jafari (2007) argue that the city of Tehran has a high overall vulnerability to earthquakes due to the considerable vulnerability of antiquated urban areas within the city. In order to enhance the existing urban structures three essential items must be evaluated by construction practitioners and disaster management teams: (1) Building Damage Index, (2) Evacuation Index, and (3) Secondary Damage Index (Hosseini and Amini Hosseini, 2008).

Building Damage Index refers to the ratio of potential building collapse against the total number of buildings in an area. Amiri, Motamed, and Eshagi (2003) explain that it is not only the type of building or its condition that must be evaluated but also local site variables such as soil types, geotechnical characteristics of sediments, and topography. All of which are crucial factors which may contribute to major damages in structures and lifeline systems. A key reason for the importance of site evaluation in Tehran is the multitude of various soil types across the city. Furthermore, the development of high-rise buildings in densely populated areas also increases vulnerability. Tehran Municipalities could mitigate this vulnerability by not permitting the development of buildings above a specified height in densely populated areas, however, no such action has been taken by the Tehran municipality, who are themselves the main shareholder of profits gained from issuing such building permits (Zolfaghari, 2006).

Evacuation Index refers to the evacuation system of urban areas including open spaces, narrow roadways, number of evacuees and the capacity of an earthquake. Amini Hosseini and Jafari (2007, p.127) argue that emergency roadways require a sufficient width (a minimum roadway width equal to one-fourth height of the buildings for each side of the roadway) to minimize the risk of blockage after a seismic event and ensure the feasibility of rescue procedures. Hosseini and Amini Hosseini (2008) propose that safe evacuation spaces must be clearly identified in advance to endorse the actual usage of said evacuation spaces and maps in an emergency to allow for the efficient evacuation of persons. The provision of emergency road maps, the development of mid to long-term shelters, and the designation of community evacuation spaces could significantly reduce the losses during and after the occurrence of an earthquake (Hosseini, Mohaymany, and Movini, 2006).

Secondary Damage Index refers to the potential damages sustained by hazardous facilities located within urban areas such as gas pipeline and distribution networks, power distribution networks and fire protection systems. In order to mitigate seismic impacts, it is necessary to strengthen existing infrastructures and lifelines. Primary lifelines and infrastructures within the city of Tehran include major transportation bridges, water processing and distribution networks, gas pipeline and distribution networks, and power distribution systems (Hosseini and Amini Hosseini, 2008).

2.8.3. Establishing Disaster Mitigation Policies Such as Insurance

It is evident that through detailed knowledge of previous disaster impacts and the available methods of risk reduction, promoting a culture of insurance within the construction industry can significantly benefit-risk reduction (Zolfaghari, 2006; Hosseini and Amini Hosseini, 2008). Although insurance is not a complete solution, it does however successfully transfer a portion of the risk. For example, Turkey's public-private insurance scheme was remarkably successful in risk reduction after Turkey's last disaster occurrence (Khatamee, cited in UN 2004). In developed countries, the share of costs borne by insurance companies relating to a natural disaster is approximately 40%, while in developing countries such as Iran, this proportion is usually less than 1%, which at present is not sufficient to insure even local government assets (Amini Hosseini et al., 2013). The additional problem is that Iran's insurance market lies primarily within the purview of the government, with private companies having only a minimum share of the market, thus further increasing the financial responsibility of the government regarding disaster events. Therefore, the adoption of strong financial and legislative policies to regulate construction practice standards and the involvement of private insurance companies within the regulatory policies could improve the seismic resistance of buildings and reduce overall damages and losses (Vaziri et al., 2010).

2.8.4. Construction Practitioner Compliance to Laws and Regulations

The Iranian Studies Group (2004) expresses that the lack of existing building code enforcement is one of the key factors having a negative impact upon earthquake risk management in Tehran. In an investigation conducted into the Bam Earthquake (2003), Manafpour (2003) reports on several issues relating to existing construction practices and regulations: (1) Professionals are only familiar with basic building design and drawing preparation without any consideration being placed upon the seismic design. (2) Official guidelines to accompany and clarify building codes for practicing engineers are limited. (3) Persons working within the construction industry are often unskilled or unlicensed. (4) A lack of oversight in the supervision and approval of construction. It is a commonplace that the construction engineers themselves take on the responsibility of design approval. (5) An absence of regulation in regards to land and property planning, particularly in the suburbs of the city.

In a study conducted into the achievement of earthquake hazards mitigation in Iran which assessed progress in the advancement of building codes, design regulations, supervision standards and construction material standards. Ghafory-Ashtiany et al. (2000) determined that only 50% percent of reforms have been achieved based upon the current Iran Earthquake Hazard Mitigation Program (IEHMP), however, this progress is not sufficient to effectively cope with the impacts of a potential major earthquake in Tehran.

2.8.5. Avoidance Unethical Behaviour of Construction Practitioners

Ho (2003) determined that one contributing factor which facilitates unethical behaviour within the construction industry is poor implementation of the standards of ethical practice, due primarily to the absence of engineer supervision. Trevino et al. (1999) state that engineers' disregard of standard ethical practice is due to a lack of formal ethical training programs in the workplace. Tow and Loosemore (2009) state that the most commonly perceived contributors of unethical practices within the global construction industry are poor ethical training, time and budget pressure, high-level competition and individuals seeking personal gain. Therefore, the improvement of education in the context of construction ethics is essential to avoid structural failure due to negligence or unsafe works.

Engineers are expected to exhibit the highest standards of honesty and integrity in their field (Sinha et al., 2004). Unethical practice, within the context of construction, refers to a failure to ensure compliance with the protocols of construction standards. King et al. (2008) outline twenty-four unethical construction practices observed in Taiwan, which are also applicable to the construction industry in Iran. These unethical practices include a lack of government inspector oversight, non-compliance with regulations, competitor capacity exaggerations, the unfair treatment of contractors during tender proceedings, the absence of licensing and accreditation procedures, a lack of safety ethics by contractors, bid undercutting, strategic overpricing, and a profit-first mentality. Unethical practices on the part of construction practitioners ultimately serve towards a reduction in building and infrastructure quality and an increased risk of damage in the event of an earthquake.

2.8.6. Implementing the Role of Construction Practitioners in Disaster Mitigation Policies

The improvement of earthquake management policies to protect against seismic hazards is not possible without the participation of construction practitioners. One example of the potential contributions which construction practitioners can provide is that they "*can play a major role in disaster mitigation by creating safe structures through the integrated efforts of all those involved in the construction process*" (Patel, 2010, p.29). Construction practitioners occupy an array of positions within the construction industry including: policy makers, city planners, structural engineers, geotechnical engineers, hydrological engineers, environmental engineers, surveyors, transportation engineers, marine engineers, service engineers (HVAC, electrical, fire-fighting, vertical transport, plumbing), site supervisors, site engineers, consultant engineers, architects, contractors, academic researchers, and end users of developments such as building proprietors. In this research, construction practitioner positions are applicable to governmental authorities, construction engineers and proprietors.

The enhancement of construction quality towards increased seismic resistance is not possible without the involvement of the engineering community as a whole; their participation should be in all stages of construction including design, execution, supervision, and maintenance. Naderzadeh and Moinfar (2004) explain that poor design, a lack of control over structural drawings during the design control phase, and an absence of effective supervision by qualified engineers all serve to increase structural vulnerability and risk against seismic activity in Tehran. Ghafory-Ashtiany (2006) also refers to the lack of technical supervision or implementation of existing knowledge by construction engineers. According to research conducted on weak-story buildings in Turkey by Kirac et al. (2011), a majority of buildings were constructed without engineering supervision, and without seismic design considerations. They state that a majority of these buildings "*suffered severe damaged or collapsed during strong ground excitation*" (Kirac et al., 2011, p.571).

The Tehran municipalities and other authorities such as road, energy, civil defence and telecommunication also have a significant role to play in the mitigation phase of the disaster management cycle. In order to prevent the damages from an earthquake, it is necessary to increase the knowledge of local government employees and related organizations (Mehdian et al., 2004). The awareness of engineering authorities in regards to building and lifeline damages sustained during earthquakes is highly crucial, and there must be appropriate programs in place which ensure their education and preparedness. The engineering community's awareness of the vulnerabilities pertaining to seismic events and their preparedness to construct seismic resistant buildings is of paramount importance. Therefore, it is essential to thoroughly understand the roles played by authorities, construction engineers and developers within Tehran's earthquake risk mitigation plan.

2.9. The Role of Construction Practitioners in Earthquake Disaster Management

The activities of communities, individuals, construction practitioners and engineers in cooperation with the local and national government can provide beneficial risk reduction results within built environments. Earthquake risk management focuses upon undertaking measurable efforts towards disaster risk reduction. Hence, the role played by the engineering community in relation to all aspects of earthquake risk mitigation can be used to evaluate the best potential approaches towards disaster risk management (Özerdem and Barakat, 2000; Seismic Safety Commission, 2000). Construction practitioners have a professional responsibility to implement diverse strategies throughout the various stages of the disaster management process (preparedness, mitigation, response, and recovery). The roles played by construction practitioners, in the context of earthquake risk reduction, can be divided into three distinct categories: (1) municipalities and authorities, (2) professional engineers, and (3) building owners and landlords.

2.9.1. The Role of Municipalities and Authorities Engineers

Municipalities and authorities, serving as authorized entities of local government, have the capability to dramatically decrease the degree of risk in built environments and urban areas. The primary role of municipal engineers, at all levels of government, is in the mitigation and prevention of disaster (Lixin et al., 2012). It is widely understood that municipalities have direct control and responsibility over the disaster management process and availability of social services within their respective jurisdictions. Moreover, municipal town planning and regulations indirectly affect the capability of an urban area to cope with the impacts of an earthquake event. For instance, the distribution of infrastructures and public services in a city determines the location of residential habitation (Zolfaghari, 2006). Furthermore, local governments can decrease disaster risk through town planning activities such as the identification of appropriate locations for emergency shelters which may be required in the event of a disaster (UN, 2004). In a review conducted by Dodman et al. (2013), they outline the role of municipalities in disaster prevention and response. They consider a range of variables to determine the level of contribution made by local administrations in each activity (Table 2-3).

Table 2-3: The Role of City Government in Disaster Risk Reduction (Dodman et al., 2013)

Role for City/Municipal Government	Long-Term Protection	Pre-Disaster Damage Limitation	Immediate Post-Disaster Response	Rebuilding
BUILT ENVIRONMENT				
Responsive, Appropriate and Enforced Building Codes	*High*		*High*	*High*
Land Use Regulations and Property Registration	*High*	*Some*		*High*
Public Building Construction and Maintenance	*High*	*Some*		*High*
Urban Planning (Including Zoning and Development Controls)	*High*		*High*	*High*
INFRASTRUCTURE				
Piped Water Including Treatment	*High*	*Some*	*High*	*High*
Sanitation	*High*	*Some*	*High*	*High*
Drainage	*High*	*High*	*High*	*High*
Roads, Bridges, Pavements	*High*		*High*	*High*
Electricity	*High*	*Some*	*High*	*High*
Solid Waste Disposal Facilities	*High*	*Some*		*High*
Waste Water Treatment	*High*			*High*
SERVICES				
Fire-Protection	*High*	*Some*	*High*	*Some*

Public Order/Police/Early Warning	*Medium*	*High*	*High*	*Some*
Solid Waste Collection	*High*	*High*	*High*	*High*
Schools	*Medium*	*Medium*		
Healthcare/Public Health/Environmental Health/Ambulances	*Medium*	*Medium*	*High*	*High*
Public Transport and Transport Management	*Medium*	*High*	*High*	*High*
Social Welfare (Includes Provision for Child Care and Old-Age Care)	*Medium*	*High*	*High*	*High*
Disaster Response (Over and Above That Listed Above)			*High*	*High*

The United Nations Office for Disaster Risk Reduction (UNISDR) describe ten essential measures which should be implemented by local governments towards the increased resilience of a city (UNISDR, 2012), as represented in Table 2-4.

Table 2-4: Local Governments' Essential Steps Towards Making Cities Resilient (UNISDR, 2012)

	Essential Actions of Local Government
ESSENTIAL 1	Put in place organisation and coordination to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role in disaster risk reduction and preparedness.
ESSENTIAL 2	Assign a budget for disaster risk reduction and provide incentives for homeowners, low-income families, communities, businesses and the public sector to invest in reducing the risks they face.
ESSENTIAL 3	Maintain up-to-date data on hazards and vulnerabilities prepare risk assessments and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city's resilience are readily available to the public and fully discussed with them.
ESSENTIAL 4	Invest in and maintain critical infrastructure that reduces risk, such as flood drainage, adjusted where needed to cope with climate change.

ESSENTIAL 5	Assess the safety of all schools and health facilities and upgrade these as necessary.
ESSENTIAL 6	Apply and enforce realistic, risk compliant building regulations and land use planning principles. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible.
ESSENTIAL 7	Ensure education programs and training on disaster risk reduction are in place in schools and local communities.
ESSENTIAL 8	Protect ecosystems and natural buffers to mitigate floods, storm surges, and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices.
ESSENTIAL 9	Install early warning systems and emergency management capacities in your city and hold regular public preparedness drills.
ESSENTIAL 10	After any disaster, ensure that the needs of the affected population are placed at the centre of reconstruction, with support for them and their community organisations to design and help implement responses, including rebuilding homes and livelihoods.

In addition to criteria provided in the above table, the UNISDR provides training programs relating to earthquakes and the responsibilities of local authorities to ensure that the governing bodies are aware of the measures which must be taken in hazardous situations. Dodman et al. (2013) state that the interaction between local and national government plays a critical role in the reduction of public risk. They highlight the importance of the state government's financial support of local authorities.

It can be concluded that Tehran's municipalities and authorities must ultimately bear the responsibility for the overall development of the city and its districts. Hence, they must be obligated to implement necessary policies such as setting up appropriate regulations for building completion, the enforced prohibition of illegal construction practices, vetting procedures to verify construction engineer certification, and the frequent evaluation of construction engineer performance. Furthermore, quality assurance and regulated material testing during construction should be made mandatory. Another important policy which should be implemented by Tehran municipalities is the thorough inspection of all construction prior to issuing the necessary permission for building usage; the success of this strategy can be observed in Dubai, the United Arab Emirates, which maintains strict regulations over all aspects of building design, construction and completion approval.

2.9.2. The Role of Professional Engineers

The presence of professional engineers within engineering firms such as contractors, consultants, and developers are of critical importance in order to minimise death, damage and other negative consequences associated with earthquake hazards (Mohorovcic, 2009; Bozorgnia and Bertero, 2006). These qualified individuals along with their engineering firms play a vital role in the risk reduction phase of the disaster management cycle. They can be capable of performing pre-disaster risk reduction activities such as pre-planning and the provision of informed recommendations for construction practice, the development of detailed construction designs, and qualified construction supervision. They are also able to actively participate in the post-disaster recovery phase. One example of construction engineers' participation in disaster risk reduction is the improvement of infrastructure and construction quality. The role played by professional engineers with respect to the enhancement of infrastructure and construction quality in the pre-disaster and post-disaster phase opens a vast research area. Earthquake professionals firmly believe in the importance of design quality (Lim, 1991). Seismic-safety professionals address the quality of construction materials as an important factor; they also emphasize the quality of construction and implementation phases of a new building or the retrofit of existing buildings (e.g., FEMA, 2015; FEMA, 2008; Naderzadeh, and Moinfar, 2004).

In the last decades, considerable effort has been made towards the development of knowledge and skill in the design and construction of new generation buildings with increased seismic resistance. The design of resistant infrastructures such as levees and the use of flood-resistant materials such as pressure-treated (PT) or marine grade plywood are some examples of technologies utilized in these new generation projects (Hamburger et al., 2004). In the context of earthquake hazards, the type of structure has a significant role in determining the vulnerability of a structure. Scientists recognize that the greatest risk to life comes from structural damage and the collapse of certain buildings which are not resistant to earthquake forces (Seismic Safety Commission SSC, 1987; UNCRD, 2009). Key (1995) determined that unreinforced masonry (URM) buildings are the type of building most vulnerable to collapse during an earthquake event; such buildings are commonplace in countries such as the United States of America, Mexico, Armenia, Iran, China, Peru, and others.

In surveys conducted by Naderzadeh and Moinfar (2004), and Hosseini and Amini Hosseini (2008) into the types of structures present in Tehran, the results indicated that 80% of the buildings are constructed using unreinforced masonry which, in the case of a strong earthquake, are extremely vulnerable. Architects in Tehran commonly select unreinforced masonry as these buildings *"provide total freedom to design any plans, without worrying about the location of columns or implementing any bracings*" (Naderzadeh and Moinfar, 2004). Other common examples of poor design practices in Tehran are the inappropriate connection of infill walls to frames and the lack of structural bracings which often result in structural failure due to seismic forces. Mehrabian and Haldar (2005) explain that a disregard of the fundamental principles of earthquake-resistant design caused a significant amount of structural damage in the city of Bam/Iran. They determined that many buildings have been poorly designed due to the designers being either untrained or without the sufficient experience to meet the requirements of the seismic-resistant design. They conclude that the Bam Earthquake is a prime example of the possible dangers of ill-conceived structures (Mehrabian and Haldar, 2005).

The quality of construction is also dependent upon when the building was constructed and to what degree seismic codes are utilized in the design and construction supervision (Tasnimi, 2001). Therefore, one of the best ways to increase overall earthquake safety is to improve the building design and specification of construction materials (Smith, 2004). Ghafory-Ashtiany highlights that "*poor code and law enforcement, lack of technical supervision, and high dependency on weak infrastructures and services*" (cited in UN, 2004, p.3) are the most common problems within Tehran's construction industry when considering earthquake events. While results show that building materials such as steel and reinforced concrete frames are less vulnerable (Naderzadeh and Moinfar, 2004), the results also indicate that the quality of construction in terms of materials and workmanship can decrease vulnerability. Grünthal et al. (1998) propose a method named "The Vulnerability Table" for categorizing the seismic vulnerability of various types of the structure into six classes, A-F, based on the strength of the structures.

In addition to the damages and losses associated with structural collapse due to inadequate construction materials or poor design, non-structural factors also have significant importance in the vulnerability of a built environment. Scientists believe that effective safety system designs, alongside competent structural design, can stimulate disaster risk reduction (e.g., Geschwind, 1996; Mousavi et al., 2008; Bozorgnia and Bertero, 2006). Amongst the non-structural parameters, the post-earthquake fire has risen to a high level of importance in literature. For instance, the construction of the building should withstand fires generated from earthquakes for “*a minimum duration as required for a desired level of performance*” (Mousavi et al., 2008, p. 689). They argue that non-structural protection schemes such as fireproof doors, fire and smoke detection systems, fire extinguishing systems and sprinkler systems can decrease the impact of fire hazards deriving from an earthquake (Mousavi et al., 2008). In contrast, gas pipelines present within residential dwellings significantly increase the risk and probability of building damage due to fire. These factors highlight the importance of developing the relevant building codes of practice, planning, and standards in non-structural protection. These standards vary from country to country, and the advancement of such regulations is not possible without the guidance and participation of dedicated professional engineers.

Construction professionals must also interact with local governments in order to develop efficient town planning and resource management services (Zolfaghari, 2006). In consideration of the number of people or assets that could potentially be affected by an earthquake disaster, it becomes evident that the height and a population density of buildings plays a major role in the management of disaster risk (Manafpour, 2003). Hence, the reconstruction of high-rise buildings and skyscrapers within close proximity to fault zones could directly serve to harm more people and assets (Zolfaghari, 2006). This perspective emphasizes the vital significance of administering proper town planning. Construction professionals, in cooperation with local governments, could assist in the development of appropriate land use planning through the restriction of construction in hazardous areas thereby resulting in the reduction of urban vulnerability. However, although the development of proper town planning strategies and the implementation of construction practice codes is a major step towards improved risk mitigation, the enforcement of such regulations is critical to a successful implementation process (Pheng et al., 2006).

The age of buildings and infrastructure is another key factor which contributes to the seismic vulnerability of a built environment (Zolfaghari, 2006). The probability of collapse is often greater in older buildings due to non-compliance with seismic code standards. Therefore, the retrofit of existing buildings and strengthening of aged infrastructures is a consequential task which should be addressed by professional engineers. Bradshaw et al. (2011) confirm that the retrofit of existing buildings could serve to mitigate “*the risk of lives and financial losses*” (P.7). The selection of an appropriate retrofit method is often contingent upon strength and ductility improvements, the availability of skilled labors, the quality of construction materials, and the cost implication said retrofit works which must be evaluated by professional earthquake engineers (Bradshaw et al., 2011).

Construction engineers also have a fundamental role to play in post-disaster activities including both the emergency recovery and response phases. The evacuation of persons from the disaster area, the emergency rescue of victims, and the construction of temporary shelters immediately after the catastrophe all help to reduce the overall damage caused by the hazard (Lizarralde and Boucher, 2004; Young, 2004). Furthermore, the restoration of damages sustained by infrastructures such as roadways, bridges, hospitals, water supply, electricity, and communication lines all serve to reduce the final total of disaster damages (Jigyasu, 2002; Jigyasu, 2004). Many scholars discuss the importance of building information modelling for emergency response and relief (e.g., Isikdaga et al., 2008; Aziz et al., 2009). They believe that building information modelling has a great potential for assisting search and rescue activities after the occurrence of a disaster. Therefore, construction engineers have a direct responsibility towards the preparation of temporary sheltering and the restoration of public services. (Haigh & Amaratunga, 2010).

Construction professionals play a broader role in the recovery and reconstruction phase. Amin, Cox, and Goldstein (2008) provide a long-term perspective which states that reconstruction and rehabilitation is a long process. In the recovery phase, all key parameters of construction practice such as the quality of design and execution of construction works must be taken into consideration in order to provide buildings and infrastructures with greater resistance to future hazards. The development of knowledge and skills within the construction industries of developing countries is crucial to ensure the feasibility of complex reconstruction processes. Inappropriate management, which may result in project cost overruns and delays, coupled with the disregard of building codes and land-use planning, commonly results in the poor quality of completed construction thereby increasing the complexity of the reconstruction phases.

As per all previous literature reviews presented in this research and the recorded impacts of recent earthquakes in the region, expert engineers across the various fields of construction should take responsibility towards the improvement of their respective projects to ensure that safe, economical and efficient structures are delivered. From the perspective of a structural engineer, the irregular shapes of buildings and the irregular orientation and shape of columns should be avoided whilst ensuring compliance with the latest construction design and practice codes (Murty et al., 2012). Structural stability and performance should not be compromised by or substituted for more economical alternatives. Furthermore, quality control and site supervision should be supervised by experienced technical personnel whilst ensuring that all engineers are familiar with the various practice standards including earthquake codes and ductile detailing requirements (Murty et al., 2012, p.10).

Builders and contractors have a responsibility towards the execution of construction and quality control at the site, whilst developers and end users have a responsibility towards the acknowledgment of construction works including earthquake safety regulations and standards (Patel, 2001). From the perspective of a building contractor, construction works should only commence after obtaining approval from all necessary authorities and the completion of all architectural, structural and other required design drawings (Patel, 2001). All construction should be executed in strict compliance with the relevant design drawings with no modification being implemented without consulting the engineers. Soil investigation studies should be conducted through reputed agencies as per the site conditions and verified by engineers and governing authorities (Patel, 2001).

2.9.3. The Role of Building Owners and Landlords

Research conducted by several scholars indicates that successful risk reduction projects involve public community engagement (e.g., Ghafory-Ashtiany et al., 2000; Wenzel, 2006; Hosseini and Amini Hosseini, 2008). Community involvement within the disaster management cycle has the ability to transform a vulnerable community into a disaster prepared community. Promoting a culture of prevention thereby reducing disaster vulnerability is a significant step forwards in the overall reduction of disaster risk, however, fostering a culture of prevention through raising public awareness is a time-consuming and challenging process that requires a community with the knowledge and willingness to cope with the impacts of a disaster.

Proprietors and landlords, as members of the community, can undertake various measures towards the reduction of disaster risk such as investing in the quality and integrity of their properties (Patel, 2001). They could also contribute to the disaster risk management process by relocating their investments away from areas with high levels of vulnerability (Adamo, 2010; Tacoli, 2009; Warner, 2010; Bohle et al., 1994). In some cases, the proprietors could also be directly involved in the construction of small buildings and infrastructures (Pelling, 2011, Dodman et al., 2013). Although property owners do not have direct control over disaster risk reduction regulations, land-use planning or building code standards, they could potentially encourage, support, and in some cases, force the local government and engineering communities to develop and implement certain norms and rules (Soltesova et al., 2012). Another important factor is that property owners must not sacrifice safety for economic savings. They should also ensure the regular maintenance of their properties and that any irregularities are brought to the attention of the relevant authorities should they be discovered (Patel, 2001).

Patel (2001) argues that based on the lessons learned from recent earthquake events, occupants and tenants, as members of the community, could increase their safety requirements when occupying the property. He also argues that the occupants and tenants, prior to occupying the property, must ensure that the relevant authorities have sanctioned the construction and that reputed consultants and contractors were involved in the construction; hence, proper quality control measures have been taken (Patel, 2001, p.601). Nateghi (2001) states that granting tenants protective rights could ultimately force landlords to upgrade the condition of their properties and safety provisions. Tenants and landlords alike should be aware of construction practices and existing regulations. They should also ensure that the properties are fully insured by a credible insurance provider and that they are prepared and provisioned for any emergencies in the event of a natural disaster. Furthermore, they should inform the architect and structural engineer of any changes in the building and that if any irregularities are discovered in the construction. The landlords and tenants should ensure that the buildings and its services are properly maintained at regular intervals as per applicable regulations.

2.10. Awareness and Preparedness of Engineers to Earthquake Disaster in Tehran

According to the equation defined by UNESCO in 1978, earthquake risk can be calculated as follows:

[Earthquake Risk] = [Earthquake Hazard] ∗ [Structural Vulnerability] × (Value or Loss)

This equation exhibits that "*earthquake risk is made up of the earthquake hazard, the vulnerability of the structure and the value or loss, each of which involves a range of specialties*" (Algermissen et al. 1979 cited in Ambraseys, 2009, p. XII). Earthquake hazard which refers to earth sciences such as tectonics, seismology and engineering seismology involves specialists such as earth scientists. The structural vulnerability which refers to the structural susceptibility of buildings and materials lies under the purview of a different field of professionals such as earthquake engineers, structural engineers, site engineers and skilled workers within the various fields of construction. Hence, the earthquake risk would increase if the construction industry chooses to employ unskilled workers or underqualified engineers.

The implementation of seismic building codes can significantly increase the seismic resistance of buildings when the engineers that implement the codes accept its value, endorse its use, and understand the codes and design criteria required of them (Nateghi, 2001, p.207). Furthermore, such codes should be fully enforced and assessed by municipal engineers ensuring compliance with construction standards. The awareness and morality of engineers in Tehran are critical to avoid the construction of substandard buildings which would be vulnerable to an earthquake disaster (Ghafory-Ashtiany et al., 2000; Wenzel, 2006; Manafpour, 2003). Construction practitioners must understand that the disregard of hazards has the potential to turn an earthquake into a disaster. People's decision to invest or enable projects without first considering the hazards is common due to "*the lack of awareness and technical knowledge to alleviate such risks*" (Ambraseys, 2009. P. Vii). Wenzel (2006) states that poor professional standards and ethical practices ultimately compromise the quality of construction thereby increasing urban vulnerability.

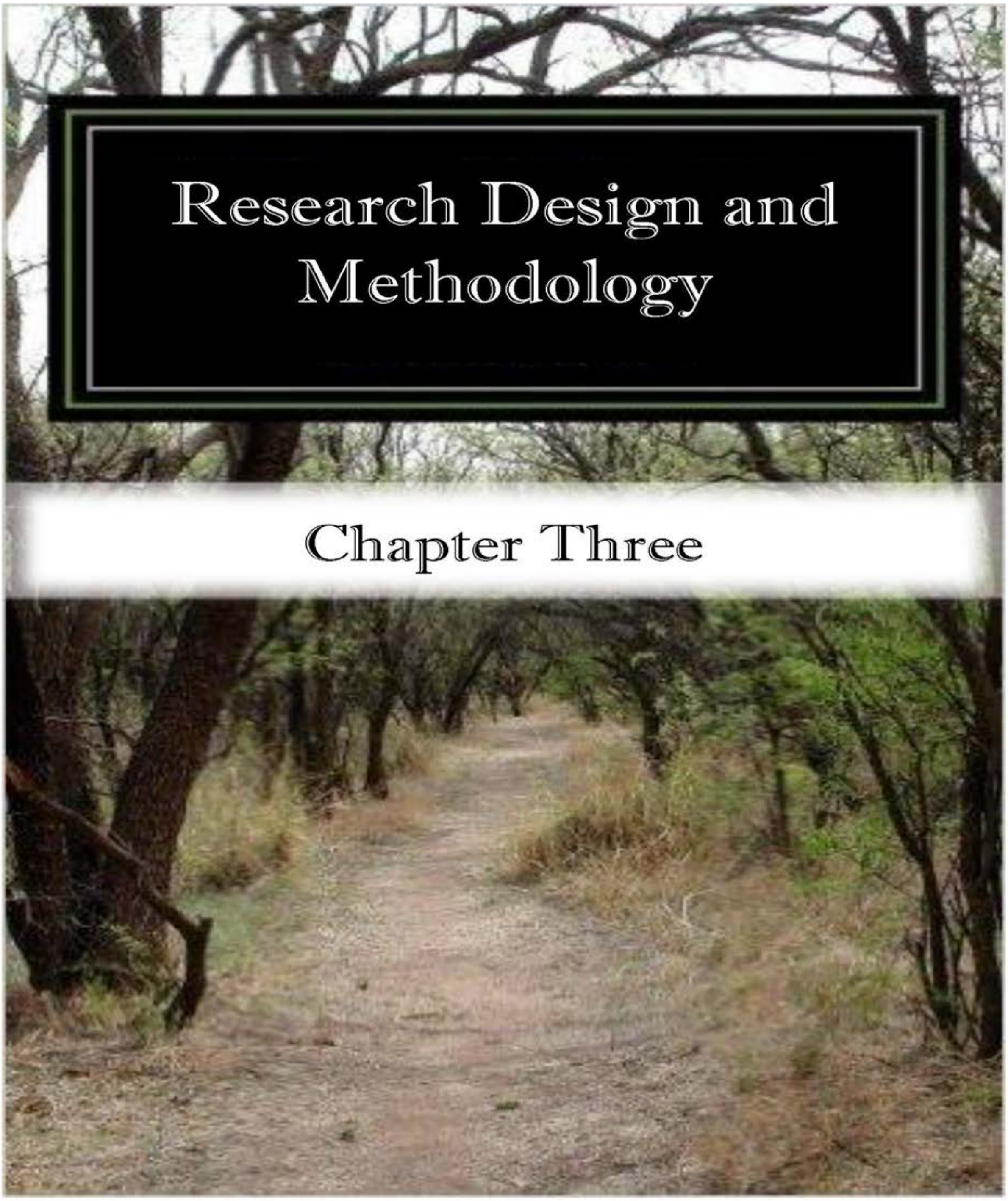
According to an interview held by Tabassi and Abu Bakar (2009), there are no credible statistical reports which assess the number of skilled workers and unskilled workers currently employed in Tehran. Furthermore, there is an absence of reliable information regarding the number of qualified engineers within the different fields of construction in Tehran whom may be or may not be aware of seismic codes and regulations. Zolfaghari (2006) argues that in some cases the negligence of construction engineers may not be due to a lack of knowledge regarding hazards and vulnerability but instead due to a conflict of interests relating to investment profits; subsequently resulting in the disregard of construction standards and codes.

Mehdian et al. (2004) propose a plan for the preparedness and response phases of Tehran's disaster management cycle in which they highlight educational provisions within the construction industry applicable to all practitioners such as governmental authorities, professionals, and engineers. These provisions are composed of: *"(1) understand the basic knowledge of earthquakes, (2) awareness of rules and regulation related to seismic codes and (3) awareness of the results of estimate damages and vulnerabilities related to earthquakes in Tehran*" (p.7). The importance of education regarding vulnerability and the damages of earthquakes is imperative within the construction industry as some engineers believe earthquakes to be a severe threat but consider earthquake preparedness to be too difficult (Ghafory-Ashtiany, Jafari, and Tehranizadeh, 2000; Krimgold, cited in UN 2004). One could question whether the engineers in Tehran are provided with sufficient information and resources which would enable them to plan for the reduction of seismic hazard impacts effectively.

Nateghi (2001) and Gharaati (2006) explain that formal training is one of the most practical techniques for improving the awareness of construction practitioners. Professional training is an integral component of the variety of mitigation methods which are available to Tehran's overall disaster management plan. Manafpour (2003) refers to the existence of improper construction design which leads to increased vulnerability during the Bam Earthquake. This was due to the lack of seismic training programs for design engineers regarding the safe design of structural and non-structural elements. He continues that "*effective training has not been provided for many professionals who are only familiar with general building design and preparation of drawings without any seismic design considerations*" (Manafpour, 2003, pp.55-56). The effective training of construction professionals could be provided by universities or through part-time courses provided by institutes such as the Iranian Society of Engineering. Alternatively, training could be provided through seminars, the implementation of instructors in the workplace, online education programs, or other resources which are available to those who wish to gain useful knowledge of seismic codes and design. The formal training of unskilled workers is also a valuable method which should implement within Tehran's construction industry as an array of research confirms that a significant proportion of Tehran's low-quality construction is due to a lack of skilled workers. (Tabassi and Abu Bakar, 2009; Ghafory-Ashtiany and Eslami, 1997; Akhavan, 1998).

2.11. Factors Affecting Tehran's Earthquake Disaster Management Plan

Several factors which impact the effectiveness and sustainability of Tehran's disaster management process have been highlighted in chapters 1 and 2. It has been determined through the literature review that these factors are sufficient to significantly contribute towards the development of a disaster resulting from an earthquake. The key factors which contribute to the inadequacy of Tehran's disaster management program are; (1) the absence of earthquake disaster awareness and preparedness for construction practitioners (e.g., Ghafory-Ashtiany et al., 2000; Wenzel, 2006; Manafpour, 2003; Mehdian et al., 2004), (2) deficiencies in the role played by construction practitioners in earthquake risk reduction including substandard design quality and inadequate construction materials (e.g., FEMA, 2015; Naderzadeh, and Moinfar, 2004; Moinfar, 2003), (3) the poor implementation of construction practice and an absence of effective laws and seismic building codes in earthquake risk reduction (e.g., Arian et al., 2012; Amiri et al., 2003; Nateghi, 2001; Manafpour, 2003; Mehrabian and Haldar, 2005), (4) an absence of systematic building inspections and of the role of government and authorities in earthquake risk reduction (e.g., Manafpour, 2003 ; Hosseini and Amini Hosseini, 2008; Ho, 2003 ; Trevino et al. ,1999), (5) deficiencies in the ethical practice of construction practitioners in earthquake risk reduction such as the construction of homes within disaster-prone areas (e.g., Zolfaghari, 2006), (6) a common tendency to dismiss the concept of natural hazard insurance and insufficient funding availability for the retrofit or reconstruction of buildings and lifelines (e.g., Vaziri et al., 2010; Zolfaghari, 2006; Hosseini and Amini Hosseini, 2008), and (7) the improper positioning of homes creating significant obstacles in accessing essential public services and infrastructures such as hospitals, fire stations, rescue and relief agencies (e.g., Ghafory-Ashtiany, 1999 ; Amini Hosseini and Jafari, 2007).


Research Design and
Methodology
Chapter Three

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

Creswell (2012) explains that research is “*a process of steps to collect and analyse information to increase our understanding of a topic or issue*” (p.3). He continues that researchers must follow a certain of measures when conducting research. These measures, as illustrated in Figure 3-1, consist of (1) identification of the research problem, (2) literature review, (3) research objectives, (4) data collection, (5) data analysis, and (6) evaluation and report of research.

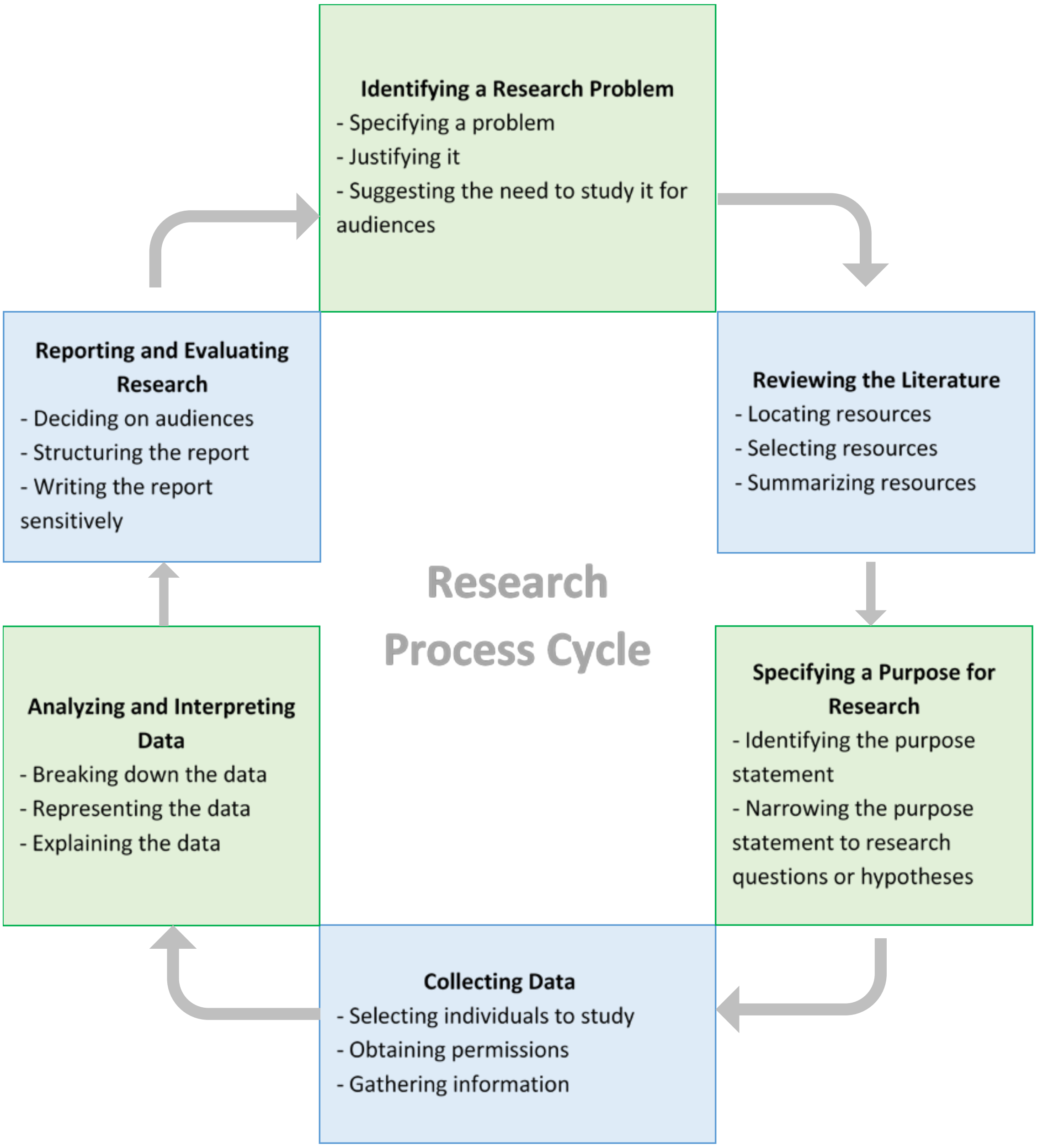


Figure 3-1: Research process cycle (Creswell, 2007; Creswell, 2012)

Identification of the research problem and the literature review have been conducted in the first two chapters of this research, while the evaluation and report of research shall be presented in chapter four of this research. Therefore, the focus of this chapter is towards providing a thorough explication of the research objectives, research methodologies and data collection methods implemented during the qualitative and quantitative data collection and analysis of the study. For this purpose, this chapter has been divided into eight articles including (1) Research questions, (2) Research design models, (3) Sampling methods, (4) Data collection methods, (5) Data collection procedures, (6) Sampling procedures, (7) Data analysis methods, and (8) Ethical issues.

3.2. Research Objectives and Questions

The initial step of scientific research is the identification of a problem followed by defining the objectives. This research shall focus on the examination of problems encountered by construction practitioners during the earthquake disaster management process in both urbanization and construction. The results of this research shall be achieved through an in-depth study of the roles of construction practitioners and their knowledge and perception of issues relating to seismic-resistant construction in the city of Tehran. The title of construction practitioner encompasses a variety of professions such as architects, engineers, contractors, consultants, earthquake professionals, disaster management professionals, property developers, landlords and local government.

This research shall attempt to determine tangible solutions relating to the obstacles encountered by construction practitioners during the construction of earthquake resistant buildings and infrastructures. The significance of this study is a crucial step towards better-enabling construction practitioners to implement proactive seismic vulnerability reduction methods. The core question which this research attempts to address is:

> "***To assess the state of awareness and current practice of construction engineers and the construction industry in preparation for seismic events and to explore the contrast between the optimal construction practices versus the current construction practices in the city of Tehran***."

In accordance to the issues discussed in the literature review and several factors which impact the effectiveness and sustainability of Tehran's disaster management process highlighted, the core question of this research can be compartmentalized into several specific questions which comply with the research subject. It is to be noted that without addressing these specific questions the researcher would not be able to determine accurate answers relevant to the core question. These questions are divided into five categories as follows:

A- Earthquake Disaster Awareness and Preparedness for Construction Practitioners:

a. Are construction practitioners aware of the significance which earthquake vulnerability plays upon social harm in the city of Tehran and to what extent are construction practitioners prepared to deal with an earthquake hazard?
b. What are the opinions of Tehran’s engineering community in regards to which buildings should be reconstructed or retrofitted and how? Moreover, how the existing infrastructures and lifelines should be improved?
c. Are construction practitioners aware of which types of structures are the most vulnerable to the impacts of seismic forces and what problems must be addressed to reduce the vulnerability of these structures?
d. Are construction practitioners aware of how the quality of construction materials can influence the seismic vulnerability of a building and what problems may prevent the use of high-quality construction materials?

B- The Role of Construction Practitioners in Earthquake Risk Reduction:

a. To what extent to do engineers and supervisors have knowledge regarding seismic design and practice codes?

b. Do construction practitioners regularly update their knowledge of standards and regulations of construction practice in relation to seismic codes and ductile detail requirements?

c. Are there any professional entities such as a civil engineering society or earthquake engineering association from which construction practitioners could obtain updated information on a regular basis?

d. How often do engineers participate in training classes or seminars conducted by professional entities?

C- The Role of Laws and regulations in Earthquake Risk Reduction:

a. Is there any intent to enhance Tehran’s urban planning to reduce vulnerability and the impacts of future seismic events? To what extent do the current construction regulations support this plan? What is the responsibility of construction practitioners in this regard?

b. Are there any laws and regulations in Tehran’s construction industry pertaining to seismic safety or do engineers follow international standards?

c. Are these laws and regulations sufficient to reduce the impacts of an earthquake and have these laws and regulations been frequently updated?

D- The Role of Government and Authorities in Earthquake Risk Reduction:

a. To what degree would the local government and Tehran municipalities bear responsibility towards the implementation of the required seismic regulations?

b. Is the responsibility of the local government and Tehran municipalities sufficient to manage disaster events and if not, why do they not wish to provide a suitable response?

E- The Role of Ethical Practice by Practitioners in Earthquake Risk Reduction:

a. To what extent do construction practitioners in Tehran feel that ethical practice is an essential component of their profession and are these professionals involved in any form of corruption or bribery which may compromise the quality of construction works?

b. Are there any ethical rules related to the construction of buildings in areas of high risk and are there any ethical codes of practice to guide construction practitioners in this respect?

3.3. Research Design

The success of any research depends directly upon the research design by which the researcher has chosen to conduct the study as a method to achieve their research objectives. According to Creswell (2012), research design refers to “*specific procedures involved in the* *research process such as data collection, data analysis, and report writing*" (p.11). There are three primary forms of research design, namely: (1) quantitative research, (2) qualitative research, and (3) combined quantitative and qualitative research including eight suitable research methodologies highlighted in Figure 3-2. In the following section, these three forms of research design shall be evaluated thus enabling the author to select the most appropriate research design method for this study.

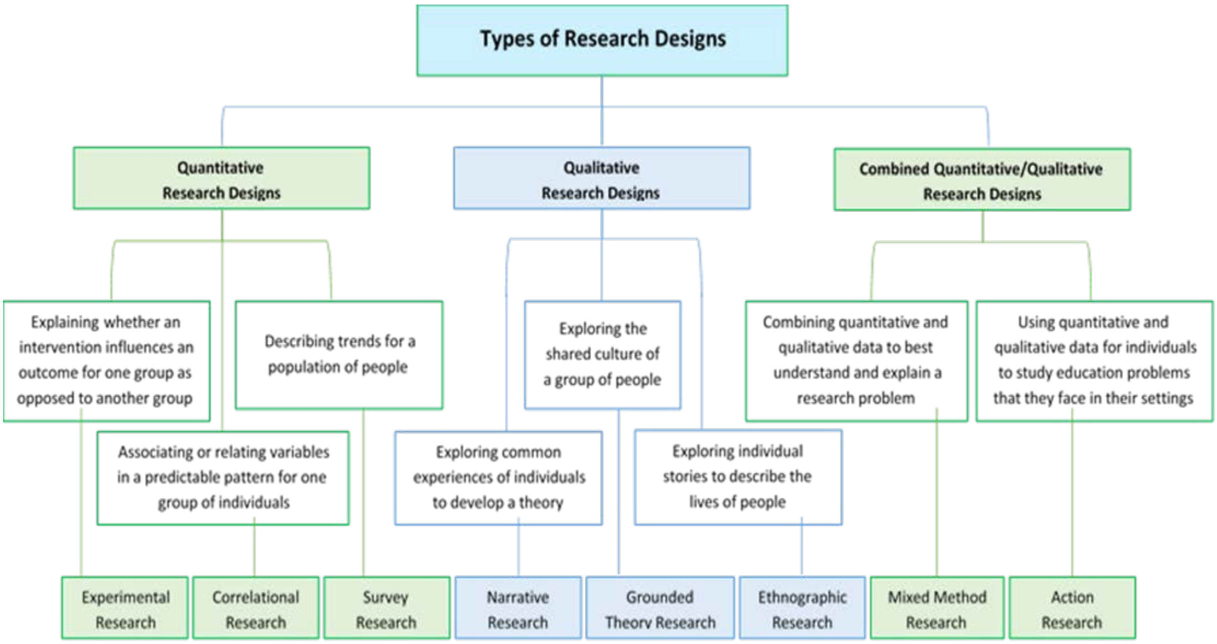


Figure 3-2 Types of research designs and their primary application (Creswell, 2012)

3.3.1. Quantitative Research Design

The primary objective of a quantitative research design is to deductively study a subject leading to either the acceptance or dismissal of the subject. In this method, closed-ended questions are proposed by the researcher to determine specific results from a hypothesis. During the data gathering process of quantitative research, the number of individuals which participate determines the reliability of the research. Hence, quantitative research often requires a large number of participants to be involved in the study. Ultimately, the data generated by quantitative research is numerical data and must be analysed statistically (Creswell, 2007; 2012).

3.3.2. Qualitative Research Design

The primary objective of the qualitative research is to understand concepts within central phenomena. The qualitative method investigates the why and how of decision making, not just the what, the where, and the when (King, 2004). The qualitative research method often enables the researcher to obtain diverse knowledge, perceptions, attitudes, beliefs, views and feelings from the respondents. Through the utilization of appropriate data gathering and interpretation methods, the researcher is then able to evaluate the respondents' perspectives in the context of the underlying concepts (Creswell, 2012).

In the qualitative research component of this research, semi-structured interviews were held, and the respondents presented with open-ended question. The proposal of open-ended questions enables the researcher to gather reliable information and assist the researched in ascertaining conclusions from varied perspectives. In other words, the proposal of open-ended questions helps to explore and better comprehend the underlying concepts of a subject matter since there are unlimited numbers of potential perspectives and answers. There are three resources to guide the interview for this research consisting of the research literature, the interviewer's personal knowledge and experience of the subject matter, and the preliminary information gathered through quantitative research methods. The predetermined spectrum of question developed by the interviewer for use in the first interview differed from the following interview questions and were modified through the use of adding probes or some ideas which were not included in the first interview. Section 3.5.5 explains interview procedure for this research and highlights the most specific questions requiring discussed.

In the qualitative data gathering component of this research, there are a limited number of twenty interviewee respondents who are experts within their respective engineering fields in Tehran's construction community. Section 3.5.6 debates the sampling in order to determine the appropriate sample size required for this research. The date generated consists mainly of descriptive data which can be utilised to form an in-depth understanding of the research subject. The research uses description as a tool to organize the data into patterns that emerge during the analysis stage. These patterns aid in the thorough comprehension of the qualitative study and its implications. The data gathered from the qualitative analysis are organised as per the research objective and utilised to generate further deductions and conclusions. Section 4.4 analyses qualitative data obtained through semi-structured interviews.

3.3.3. Combined Quantitative and Qualitative Research Design

Since neither quantitative nor qualitative research methods are sufficient to answer all questions or to provide insight on all potential issues, the strengths of quantitative research and qualitative research can be combined by researchers to develop a third method named combined quantitative and qualitative research design which may deliver a more refined inference. A combination of the qualitative and quantitative research approaches allows for the development of complete results and in-depth conclusions (Tashakkori and Teddlie 2003). Furthermore, thought the implementation of both research methods, the researcher is able to utilize one method to test the results of the other method, thus reducing response bias and ultimately mitigating research bias within the study. Researchers must utilize specific procedures to analyse the results deriving from the combination of qualitative and quantitative methods.

3.3.4. Research Design Selected for This Research

The process of determining pertinent risk reduction methods which would be successful in the reduction of earthquake hazard vulnerability through the improvement of construction practices and highlighting the consequences of which neglect of the engineering community may have upon the mitigation of seismic impacts in the region are complex multidisciplinary concepts which require a comprehensive research approach. Therefore, the selection of an appropriate research design is essential in order to develop a suitable approach towards disaster management research. In consideration of the above challenges, the author has selected to implement an explanatory sequential mixed research design which is "*a most popular form of mixed methods design in educational research*" (Creswell, 2012, p.542). In this approach, as demonstrated by Creswell & Plano Clark (2011), the researcher begins by collecting quantitative data to form a framework of the research background through the assessment of research problems. Thereafter, an in-depth qualitative exploration is conducted to evaluate and refine the research problems through the collection of pertinent qualitative data. This mixed approach offers the possibility to clearly identify the qualitative and quantitative research components to both the researcher and the audience. Another advantage of a mixed approach is that qualitative and quantitative methods can be selected sequentially whenever a single method is not sufficient to fully evaluate the research problems or when there are discrepancies present in the research results. Furthermore, a mixed research method enables the researcher to assess the results of the quantitative data though presenting subject professionals with semi-structured questions by conducting open-ended qualitative interviews based upon the quantitative data.

Although action research constitutes the main core of the DBA program, this research shall perform action research as a supplement to other methods and will not be directly implemented for practical purposes. The primary reason for this being that action research is a lengthy repeated process of seeking concepts, planning, action, evaluation of actions taken, and review of the results until the researcher is satisfied (Coghlan, 2011), which is not practical in the context of this research subject. To study the effects of earthquakes on buildings and lifelines, and to investigate the damages caused by seismic forces upon building through the process of action research would become a lengthy process and would require to be continuously implemented throughout the action and reflection. Furthermore, action research approach is based on participation and collaboration between the relevant stakeholders whom must engage in the subject with the researcher on a frequent basis and needs the full collaboration of all parties. Therefore, the implementation of action research would not be possible in the context of this study due to the lack of the author’s influence over the relevant parties and time limitations, however, the action research method will be implemented during the surveying process to identify the most suitable method of survey distribution. The action research approach shall also be used to resolve any problems which occur during the study.

In an effort to attain new knowledge and to comply with this program, the author has utilized the action research method to evaluate the retrofit of an existing building in the city of Tehran which had been executed by the author’s engineering firm to improve the subject structure’s safety factor against earthquakes. The case study which was performed into the retrofit of an existing building exercised group meetings with a focus on action research in order to generate raw information through change and reflection (Azhar et al., 2010) to identify appropriate solutions for the objective. The action research method was suitable for this undertaking since absolute practice-based research would ensure the exploration of all approaches, variables, outcomes, solutions, and risks. The findings of this case study shall be presented in a later chapter of this research and will culminate in proposals for further diagnosis, planning, and action.

3.4. Sampling Method

Considering that it may be unfeasible to include an entire population within a single study due to time constraints and resource limitations, researchers, therefore, utilize sampling methods during their research (Anderson et al., 2006). There are various sampling methods available to researchers which may be selected based upon the type of research to be conducted. Gates and McDaniel (1998) state that sampling is the only practical manner by which to collect data suitably. Sampling methods are generally categorised into four types including (1) probability, (2) purposive, (3) convenience, and (4) mixed methods. It is essential to understand that the method of sampling which is selected can significantly influence the data collection process and results. It is, therefore, necessary to acknowledge the relationship between sampling methods and research design.

The probability sampling method, in the context of quantitative research design, is the most practical sampling method as probability theories can be naturally observed in numbers, diagrams, and statistics. There are four types of sampling techniques which can be implemented in the probability sampling method including, cluster sampling, simple random sampling, multiple sampling, and stratified sampling. Logical thought would suggest that a large sample pool is superior to a small sample pool (White, 2000), however, "*it is almost better to have a smaller dataset of accurate answers than a larger one with error*" (Easterby-Smith et al., 2012, p.231).

In the context of qualitative research design, in which statistical analyses are not required, the purposive sampling or non-probability sampling methods have the potential to yield more accurate and reliable results (Tashakori and Teddlie, 2003). There are four types of sampling techniques which can be utilised in the purposive sampling method including sequential sampling, sampling to achieve representativeness or comparability, sampling using multiple purposive techniques, and the sampling of special or unique cases.

The convenience sampling method permits researchers to select easily obtainable samples; this method can be utilised in both quantitative and qualitative research designs. Although convenience sampling does offer some advantages such as time and cost effectiveness, there are however some drawbacks, for instance, the sample pool may not be sufficient to accurately represent the population (Teddlie and Yu, 2007).

Mixed method sampling, in simple terms, is a combination of purposive and probability sampling in which the element of purposive sampling increases the transferability of the research whereas the element of probability sampling increases the research's external validity. Teddlie and Yu (2007) categorize mixed method sampling into five sub-categories. Figure 3-3 illustrates the various sampling methods.

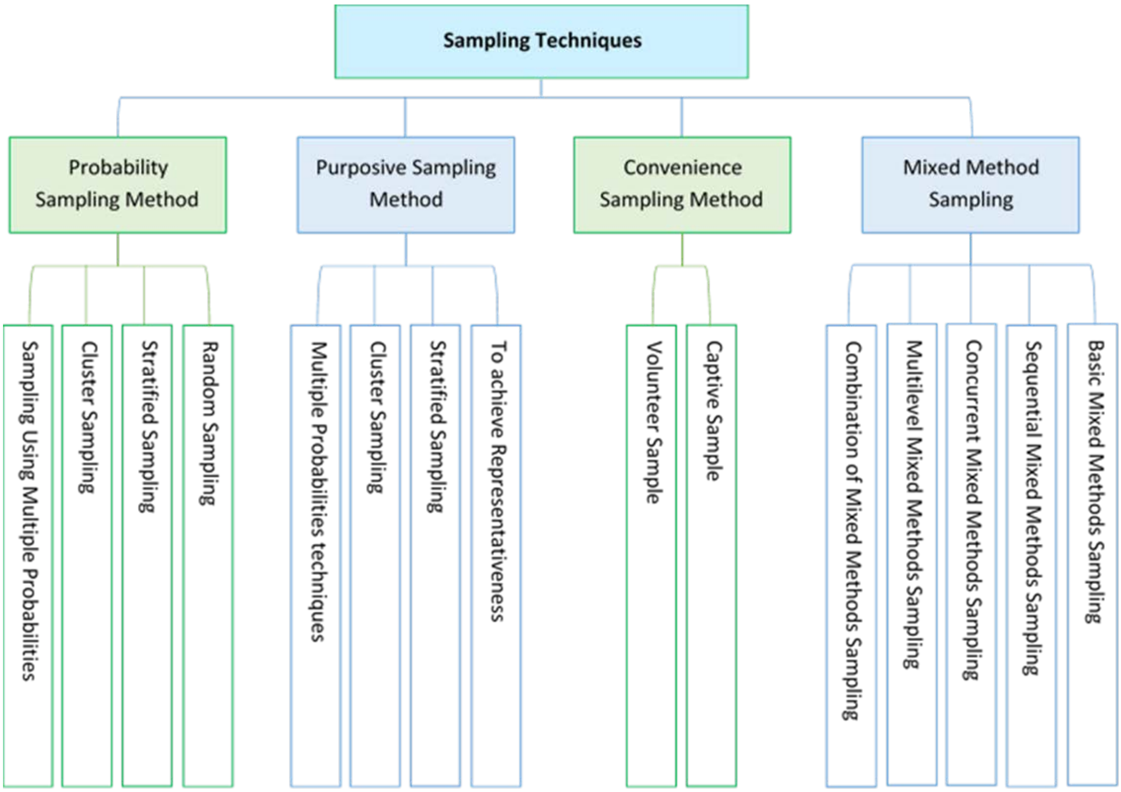


Figure 3-3: Taxonomy of Sampling Techniques (Teddlie and Yu, 2007).

3.4.1. Selecting Sampling Methods for This Research

In consideration of the above discussion and in order to obtain the most effective results from the range of sampling methods, this research shall implement a sequential mixed sampling method, namely, a sequential purposive-probability (quantitative-qualitative) sampling method. The quantitative research aspect of this study will employ a stratified sampling method. A stratified sampling method is most suitable for the quantitative research component of this study as the city of Tehran contains 22 municipal districts all of which offer varying circumstances in relation to the impacts of earthquake hazards and resulting building damages. It can, therefore, be surmised that some municipal districts, primarily those located in the older parts of the city, may require different planning and solutions to districts located in other areas of the city. It is expected that the research questions will generate a variety of responses across the city. Hence, it is essential to obtain samples from all of the districts.

Since construction practitioners commonly possess a variety of attitudes and approaches towards their profession, this research will divide these construction practitioners into subgroups, or strata, prior to obtaining the necessary samples from each subgroup in proportion to the population. Through the implementation of the stratified sampling method, the researcher is able to obtain a more representative sample than would be obtained if the simple sampling method was utilized. Furthermore, with this approach, the researcher can anticipate a smaller standard error as all of the groups are adequately represented when the strata are combined.

The qualitative research aspect of this study will utilize the sampling of special or unique cases. The sampling of special or unique cases has been selected for this research as earthquake hazards, by their own nature, are special or unique events and have long been of significant interest to scholars. Further details regarding the process of selecting the sampling methods used in this research shall be presented in the following sections.

3.5. Data Collection Method

Copper and Schindler state that the research environment provides information, known as data, to the researcher. They highlight that the most crucial descriptive factors of data are data abstractness, proximity to the study subject, and data verifiability (2003). The data required for research can be obtained from principal sources comprised of primary data sources and secondary data sources. Primary data refers to information which is gathered directly by the researcher from original sources pertaining to the current research. Secondary data refers to information which is compiled by the researcher from sources other than the current research and which has been collected by another party (Bless et al., 2006). Hence, we can understand that gathering data from primary sources results in the generation of new data providing new contributions to community knowledge. However, this contribution of new data would not be achievable without an in-depth review of pre-existing secondary data as the main data source.

In order to obtain a greater spectrum of information, this research shall assess a combination of both primary and secondary data sources which shall increase the confidence of the findings by providing multiple methods of measuring the concept. In this research, Data collection was conducted by means of three strategies. Firstly, a compilation of documentary information and theoretical studies was assembled with sourcing from journals, articles, reports, published books and online search engines named as secondary data. Secondly, an assemblage of quantitative data was collected through a paper-based questionnaire. Thirdly, qualitative data was composed through live interviews with a selected number of interviewees who had participated in the quantitative data gathering process as primary data.

3.5.1. Primary Data Collection

In consideration of the previous assessments of the various sampling methods and research methodologies, this research will utilize quantitative data collection as the dominant research collection method while utilizing qualitative data collection as the supporting research collection method. Hence, the data collection process will be conducted sequentially in which the quantitative data (dominant data) is collected first followed the qualitative data (supporting data). The qualitative data collection method (supporting) shall serve to assist the researcher in developing a logical extension of the previous findings developed during the quantitative data collection (dominant) process. There is a range of different methods, which have been assessed earlier, that can be utilized to obtain either quantitative or qualitative data. The main goal of this study is to obtain quantitative data through the distribution of questionnaires which have been designed to address all of the research objectives to the number of participants based on the accurately formulated sample size, thereafter, the qualitative data shall be obtained by conducting semi-structured interviews in accordance with the purposive sampling method.

3.5.2. Secondary Data Collection

This research shall collect secondary data from both national and international sources. A majority of the secondary data collected for this research shall be sourced from reports published by the United Nations International Strategy for Disaster Risk Reduction (UNISDR) in the year of 2016. These reports provide useful information related to the processes and strategies of earthquake risk mitigation. Additional data shall be collected from the reports published by the International Disaster Database (EM-DAT) in the year of 2016 which is a beneficial resource that provides annual listings of all global hazards events including their impacts on the affected regions. Other useful data sources such as the Atlas of Tehran Metropolis (ATM), National Disaster Risk Management Organisation (NDMO) and Tehran Disaster Mitigation and Management Organisation (TDMMO), which provide databases of Tehran's local coping strategies in relation to hazards and disaster events, will also be evaluated. Furthermore, other secondary data sources including peer review articles, publications, journal articles, newsletters, and theses relating to the subject of this study shall be utilized to provide useful concepts of the subject matter and to serve as the leading validation of the research. These data sources will be used to compose a comprehensive base of knowledge pertaining to earthquake disaster management and the role of construction practitioners in the mitigation of seismic impacts upon buildings and infrastructures within the city of Tehran. Secondary data sources shall be evaluated in order to provide adequate insight into the perceived origins and development of Tehran's disaster risk reduction processes and to thoroughly address all of the research questions and objectives.

3.5.3. Research Questionnaire: Structure, Design, and Implementation

Lewis, Saunders, and Thornhill (2008) define a questionnaire as a set of questions proposed to participants who have been selected from a sample pool. In other words, a questionnaire is an effective instrument to gather primary data and provide sample perceptions, insights, and actions pertaining to specific issues within a demographic. Therefore, questionnaires play a significant role in the quantitative data collection process due to its uniformity of data gathering from a large sample size. There are numerous reasons which justify the use of questionnaires as the dominant data source for this research; the most significant of which are listed as follows:

- The collection of reliable and valid data through interviews and group discussions is a time-consuming process further complicated by a large number of construction practitioners in Tehran. Therefore, a questionnaire is a time and cost-effective method for gathering reliable data.
- Questionnaires allow the researcher to propose uniform questions to a large number of participants while simplifying the comparison of research results.
- Questionnaires permit participant confidentiality thereby complying with the ethical conditions of this study. Thus, respondents are able to participate in the data-gathering process without any cause for bias or restriction subsequently increasing the reliability of the research findings.

In order to explore Tehran's vulnerabilities to earthquake hazards and the capacity of local construction professionals in the context of earthquake disaster management, a structured questionnaire has been developed for distribution to the selected research participants. Design of the questionnaire has been tailored for Tehran’s construction community and structured to address specific issues relating to the roles of construction practitioners in seismic impact mitigation. The majority of the questions contained within the questionnaire are comprised of polar questions in which the respondent is required to provide a yes or no answer, matrix/rating scale questions in which the respondent evaluates several items using a uniform set of choices, and ranking questions in which the respondent compares different options using a common scale. Although closed-ended questions have been primarily utilized, open-ended questions have, in some cases, been employed to obtain written feedback from the participants. Open-ended questions enable the respondents to include comments related to the research subject which the researched do not address in the questionnaire which can be used to support the quantitative data obtained by the questionnaire.

The complete questionnaire used in this research is displayed in Annexure 1. The questionnaire is comprised of five sections as outlined below:

Section 1: Demographic Information:

This section examines certain personal information of the respondents, as the general population of this research, to specify information such age, gender and level of education. This section also serves to clarify the respondents’ knowledge, experience, professional competence, and qualification within Tehran’s construction industry.

Section 2: Hazards in General:

This section determines the perspectives of the respondents regarding hazards in general and to determine the opinions of the respondents regarding the likelihood of earthquake occurrence in comparison to other hazards such as landslides, climate change, and crime, vehicle accident, etc. This section also attempts to obtain information regarding the direct or indirect experiences which the respondents may have had in relation to earthquakes or other hazards.

Section 3: Preparation for Earthquakes:

This section explores the respondents’ thoughts regarding the importance of earthquake preparedness. Furthermore, this section assesses the respondents’ awareness of earthquake impacts such as the disruption of infrastructures and the threat of damage to buildings. The respondents’ views regarding earthquake impacts coping methods and the potential methods for reducing negative impacts.

Section 4: The Construction Practitioners Roles in Earthquakes Risk Reduction:

This section explores the views of the respondents regarding built environments and the role which construction practitioners play in the reduction of earthquake impacts. The section also assesses the thoughts of the respondents regarding their perceived reasons for the vulnerability of buildings in Tehran such as building age, building height, quality of construction materials, design and implementation of construction, and accessibility of information relevant to building codes and standards. Furthermore, the respondents' views of certain unethical practices such as corruption and bribery which may affect construction projects will also be evaluated.

Section 5: Responsibility for Earthquakes' Preparation:

This section of the questionnaire evaluates the respondents' perspectives regarding the authorities (e.g., Local Government, Municipality, Society of Engineering, Disaster Management Organisation and Construction Community) responsibilities and roles in the reduction of earthquake impacts. Additionally, this section explores the respondents' perspectives regarding building code and regulatory enforcement and the presence or necessity of regulatory support for the retrofit of existing buildings for the purposes of seismic resistance. This section also assesses the respondents' opinions regarding the implementation of regulations for construction within fault-zones or unstable land and their awareness of any existing laws. Furthermore, participants are requested to provide their views regarding the three essential factors of quality, time, and cost in terms of the mitigation of earthquake impacts upon structures.

3.5.4. Pilot Testing

Piloting the final draft of questions on a small number of test participants helps to ensure that the questions are understandable and enables the researcher to resolve any ambiguities before he or she commences with the collection of data on a larger scale (Babbie, 2012). Therefore, the pilot study not only provides primary data for the qualitative analysis but also serves to provide a basis upon which the quantitative study is based. For this research, the pilot study implemented a focus group interview technique which involved six of the author's colleagues who are civil engineers and familiar with the subject of this research. All participants were in contact via formal meetings, video-conference, VOIP communications and email during the pilot study to ensure the suitability of the questionnaire for the data collection process.

Participants were also requested to provide their feedback regarding the clarity of questions and the relevance of the questions to the research subject. Furthermore, participants were asked to highlight any matters which had been overlooked or any errors which they had found in the questionnaire. The participants confirmed that the questionnaire had been well designed. However, they highlighted certain repetitions which could be excluded and some clarifications which would help to avoid any misunderstandings. The necessary modifications where implemented prior to distributing the questionnaire to the survey population.

3.5.5. Interview Procedures

Interviews are the most common method of data collection in qualitative research. This approach enables the researcher to engage in direct interaction with participants and to clarify any issues that are not easily addressed in closed-ended questionnaires. Interviews can be conducted in either an unstructured manner, in which no questions are prepared prior to the interview or in a structured manner, in which pre-determined questions are proposed to the participant. Commonly, researchers may choose to conduct an unstructured interview if they are seeking a broad spectrum of results in their research (Greef, 2007). Unstructured interviews promote free discussions thereby allowing the interviewee to feel more comfortable during the interview as opposed to the rigid interview schedule of a structured interview (Flick, 2009). Although the interviewees are the source of the research data, the role of the interviewer in ensuring the quality of the interview and collected data should not be overlooked. The interviewer should be able to efficiently manage the interview process and be a good active listener and recorder (Richards and Morse, 2007). It is possible to streamline the interview process by implementing a suitable structure to the proposed questions.

The combination of structured and unstructured interview techniques forms a semi-structured interview, which has been implemented for the qualitative data collection of this research. Semi-structured interviews typically explore specific issues and are conducted in informal and comfortable environments. In a semi-structured interview, open ended-questions based on the research objective are prepared by the interviewer in advance, and the interview will commence with the pre-determined questions. With this approach, the researcher is able to propose the interviewees with same questions but in varying orders between each participant. Although the researcher proposes the same questions to the respondents, the semi-structured method allows the interview to proceed as naturally as possible with freedom of conversation thereby gathering reliable and detailed answers (Greef, 2007). In this research, interviews were utilized to assess specific issues including:

- The role of construction practitioners, governments, and building communities such as landlords and tenants in the risk reduction process and Tehran's disaster management planning in the context of earthquakes.
- The role of universities and institutions in the reduction of earthquake risk through updating engineers' knowledge regarding seismic codes and standards.
- The significant factors that may affect the preparedness of the construction practitioners regarding potential earthquake disasters.
- The most important actions recently undertaken to reduce Tehran's earthquake impacts and some other activities, which have been forgotten, or not considered, and they are necessary to follow in the future.
- The most significant measures recently undertaken towards the reduction of Tehran's earthquake impacts, damages, and vulnerability along with any other risk reduction precautions which may have been neglected in the questionnaire that could be implemented in the future.
- The most earthquake-vulnerable districts in the city of Tehran.
- Any ethical issues which professionals have encountered relating to construction practices and the subsequent effects which these issues may have caused such as increased building damages resulting from an earthquake event.

3.5.6. Sampling Procedure

The focus of this research is upon the city of Tehran which is located in the northern-central region of the Islamic Republic of Iran. The population of Tehran totals approximately 12 million inhabitants spread over a land area of 1300 km^2 encompassing 22 municipal districts; Tehran is considered as one of the largest cities in the world. Therefore, in order to conduct thorough research regarding such a large city, it is required to formulate a viable data collection plan. As stated in the previous sections, this research will implement a mixed method sampling approach in order to capitalize upon the advantages of both the purposive and probability sampling methods.

This research has identified three primary groups of construction practitioners from which data shall be collected. Firstly, construction practitioners who are active in the construction industry such as architects, construction contractors, engineering communities and building official employees. Secondly, those who are responsible for either the development of construction codes and standards or the enforcement of construction regulations such as municipality employees, surveillance engineers, and members of Tehran’s construction engineering organizations. The second group also encompasses scientists and seismic professionals such as academic professors or members of professional entities such as the Civil Engineering Society and the Earthquake Engineering Association. The final group of respondents includes the end users, proprietors, landlords and tenants who use the building on a regular basis. This classification of respondent selection has been formulated based upon the information discussed in the literature review which investigated the various aspects of the roles of construction practitioners in relation to seismic risk reduction and shall assist in the development of recommendations suitable for minimising earthquake impacts in Tehran.

Morgan’s Table (Krejcie and Morgan, 1970) has been implemented in this research to determine appropriate sample size for the quantitative data collection. Based on the assumption that Tehran has approximately 500,000 built environment professionals operating within the city and in order to ensure a sample size sufficient to generate a confidence interval of 95% with a margin error of 5% within the proportion of the repeated population, the sample size required for this research is **384 persons** which are the maximum sample size appertaining to the above variables. This number is in accordance with The Research Advisor’s table (Table 3-1) which is directly derived from Morgan’s Table.

Table 3-1: Table to Determining Sample Size

Required Sample Size								
	Confidence = 95%				Confidence = 99%			
Population Size	Margin of error				Margin of Error			
	5.0%	3.5%	2.5%	1.0%	5.0%	3.5%	2.5%	1.0%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	146	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
1,000	278	440	606	906	399	575	727	943
1,200	291	474	674	1,067	427	636	827	1,119
1,500	306	515	759	1,297	460	712	959	1,376
2,000	322	563	869	1,655	498	808	1,141	1,785
2,500	333	597	952	1,984	524	879	1,288	2,173
3,500	346	641	1,068	2,565	558	977	1,510	2,890
5,000	357	678	1,176	3,288	586	1,066	1,734	3,842
7,500	365	710	1,275	4,211	610	1,147	1,960	5,165
10,000	370	727	1,332	4,899	622	1,193	2,098	6,239
25,000	378	760	1,448	6,939	646	1,285	2,399	9,972
50,000	381	772	1,491	8,056	655	1,318	2,520	12,455
75,000	382	776	1,506	8,514	658	1,330	2,563	13,583
100,000	383	778	1,513	8,762	659	1,336	2,585	14,227
250,000	384	782	1,527	9,248	662	1,347	2,626	15,555
500,000	384	783	1,532	9,423	663	1,350	2,640	16,055
1,000,000	384	783	1,534	9,512	663	1,352	2,647	16,317
2,500,000	384	783	1,536	9,567	663	1,353	2,651	16,478
10,000,000	384	784	1,536	9,594	663	1,354	2,653	16,560
100,000,000	384	784	1,537	9,603	663	1,354	2,654	16,584
300,000,000	384	784	1,537	9,603	663	1,354	2,654	16,586

There are no stringent rules in regards to the sample size required by a qualitative research approach. Therefore, the sample size for qualitative research can be freely determined by the researcher. In order to ensure that diversity is maintained in relation to the entire subject population, the researcher must determine appropriate sample size for the research (Nastasi, n.d.). The appropriate duration for interviews may vary dependent upon the sample size versus the scale of the database and the number of interview questions, hence, by selecting a larger sample size, the duration of the interviews may reduce. In accordance with Nastasi's (n.d.) Table as illustrated in Table 3-2, which indicates the general rule of thumb respective to each method of data collection, in-depth interviews have been selected for the collection of qualitative data in this research. Table 3-3 (Nastasi, n.d.) proposes the duration of interviews based upon the number of interviews. In order to ensure that the interview duration is sufficient to cover all aspects of the open-ended research questions, this research shall conduct interviews with a duration of **30 minutes to 1 hour**.

Table 3-2: Rules of Thumb Based on Data Collection Method (Nastasi, n.d.).

Data Collection Method	Rule of Thumb
Interviewing key informants	Interview approximately five people.
In-depth interviews	Interview approximately 30 people.
Focus groups	Create groups that average 5-10 people each. In addition, consider the number of focus groups you need based on "groupings" represented in the research question. That is when studying males and females of three different age groupings, plan for six focus groups, giving you one for each gender and three age groups for each gender.
Ethnographic surveys	Select a large and representative sample (purposeful or random based on purpose) with numbers similar to those in a quantitative study.

Table 3-3: Guidelines for Length of Interviews: (Nastasi, n.d).

Number of Interviews	Length of each interview
10	1 – 2 hours
20	30 minutes – 1 hour
30	20 – 40 minutes

Through the combination of parameters containing within the above tables, the objectives of this research determine that in-depth interviews shall be conducted with a sample size of **20 persons** with each individual interview lasting a duration of 30 minutes to 1 hour.

3.5.7. Limitations to The Data Collection Process

The primary data collection process of this research presented several unanticipated challenges. In the first step of the quantitative data collection process, numerous efforts were made to provide facilities for the online distribution of the questionnaire and data gathering. However, after approximately one month of attempted online distribution, the method had not proven effective and was subsequently discontinued.

The action research approach was implemented to identify why the online distribution of the questionnaire was unsuccessful and which methods are more practical to collect the required data. The primary cause of this failure was either the unfamiliarity of construction practitioners with the online data collection process or their unwillingness to participate in the research due to busy work schedules or a lack of interest. Further contributing factors were a lack of internet accessibility of the participants and lack of trust in web-based surveys. In consideration of the above challenges, it was determined that the quantitative data collection would be conducted through the distribution of traditional paper-based questionnaires.

The traditional paper-based questionnaire data collection approach created its own set of new challenges. Tehran is a large city with a daytime population of approximately 15 million; this resulted in significant difficulties in accessing different parts of the city due to dense traffic conditions. Thus, the distribution of paper questionnaires developed into a very time-consuming, tedious and costly data gathering process. A further challenge faced by the researcher in the data collection process was the season in which the process was conducted; the beginning of spring is an Iranian Holiday known as Nowruz during which the majority of construction companies are closed for business. This time restriction meant that the author was forced to wait until such a time that the construction practitioners has resumed work and were able to meet in person to receive and return the quantitative questionnaires and also be present for the qualitative interviews. This time-consuming process resulted in the delay of data gathering for approximately two months. Furthermore, some of the information related to the research subject was not obtainable due to political obstacles. For instance, some organizations related to the government were not willing to cooperate with the research as they believed that research being conducted by a foreign institution would not be appropriate and that there may be political repercussions. As such, some participants were not authorized to divulge particular information relating to the disaster management processes and construction standards which had been deemed to be confidential.

3.6. Data Analysis

Data analysis is a critical phase of research which aims to understand the various constitutive elements of the raw collected data and to uncover any concealed issues within the subject matter. In order to achieve this, the raw data must be precisely examined followed by the classification of identified data trends into defined groups which may assist the researcher to compose informed deductions.

The thorough analysis of collected data serves in enabling the researcher to form logical inferences relevant to key issues relating to earthquake disaster management in Tehran such as the impacts of earthquakes upon the population, the level of awareness within the engineering community, methods employed by construction practitioners in coping with earthquake hazards and reducing their impacts, the role of construction practitioners in earthquake risk reduction, and the responsibilities of government in the reduction of earthquake impacts.

The quantitative data collected using a questionnaire was be analysed by implementing the descriptive statistics method utilizing computer software such as Microsoft Excel and shall be presented in the form of tables, charts, and graphs. The significant amount of raw unstructured data obtained through the qualitative interview process is then be analysed to distinguish the pertinent information from the negligible information. Thereafter, the qualitative findings are organized as per the research objectives and used to generate further deductions and conclusions. Furthermore, in order to assess the validity and reliability of the research, data gathered from primary sources during the quantitative and qualitative data collection process is analysed against secondary data obtained from the literature review and other sources.

3.7. Ethical Considerations During Data Collection Process

There are certain ethical considerations within management research which the researcher must acknowledge during the data collection in a research process. Researchers must be aware that there may be political consequences relevant to the research subject. Access to specific information relevant to the topic of this research may only be obtained through limited channels such as government associated disaster management agencies. In some cases, these agencies may not be inclined or authorized to provide new researchers with sensitive information as there is a fear of the potential social and political repercussions once the information is made available to the general public or other concerned entities. Therefore, obtaining prior permission from government authorities in order to access data is vital and is in many cases becomes a highly arduous process.

Further ethical consideration of this research was that although there would be no physical harm inflicted upon the research participants, this particular research topic may become emotionally difficult or stressful for the participants. Therefore, the author must undertake full responsibility to ensure that the participants are protected from any potential emotional harm throughout the research process and interviews. If the research subject should become stressful for the participants at any time, the researcher must reassure the participants by highlighting the objectives of the research and its potential benefits for the community. Additionally, participants must be made aware of whom they are able to contact if they have any questions or concerns regarding the research, such as the relevant academic or scientific institutions (McLeod, 2007). The researcher must provide the participants with an information sheet outlining the general details of the research and the relevant contact information and must also obtain the participant's signature of consent via an appropriate consent form. By thoroughly informing the participants of the significance and benefits of the research, any potential psychological impacts can be minimised.

Confidentiality and the rights of participants is another ethical consideration which must be acknowledged by the researcher. The participants must be made aware that they reserve the right to withdraw from the research at any time without any justification and that withdrawal from the research will not affect their rights in any way. The participants must also be made aware that they are free to decline to answer any question. Moreover, full anonymity and confidentiality of their information will be maintained at all times, even after publication of the research. The dissemination of incorrect conclusions is another ethical consideration which must be acknowledged by the researcher. A researcher may advertently disseminate research conclusions based upon his/her own opinions, which may be inconsistent with the data collected in the research.

Whenever conducting research with mixed research methodologies, there are certain ethical considerations which must be adhered to relevant to each research methodology. Throughout the quantitative research of this study, the researcher ensures that the following ethical considerations had been observed: protection of respondent anonymity, obtaining permission from the respondents and authorities, non-disruption of construction sites, and transparent communication of the purpose of the study. Whereas during the qualitative research of this study the researcher ensures that any deceptive practices or techniques were avoided. The researcher must be aware of his potential capacity to influence the results of the data collection and must show respect to the participants of the study. Furthermore, the researcher must ensure that disclosure of sensitive information or the identities of research participants is avoided.

Chapter Four

Data Analysis and Plan Results

CHAPTER 4: DATA ANALYSIS AND PLAN RESULTS

4.1. Introduction

The primary objective of this chapter is to analyse the findings of the primary and secondary data collection. As discussed earlier, a combination of primary and secondary data analysis increases the confidence of the findings by providing more than one means of measuring the concept. This chapter shall analyse the qualitative and quantitative data collected through semi-structured interviews and the paper-based questionnaire. The data obtained from the semi-structured interviews shall assist the researcher to explore any unexpected findings generated by the quantitative questionnaire.

4.2. Secondary Data Analysis

In this section information concerning the geography, demographics, built environment and land use planning of Tehran shall be discussed in depth. All references provided in this section are sourced from the Atlas of Tehran Metropolis which is updated annually by the Tehran Municipality and available to the public online (ATM, 2016). The Atlas of Tehran Metropolis is an extensive compilation of recorded data pertaining to the geography and population of Tehran, and is a valuable reference for this research subject, for this reason, many specialist and government organisations often refer to the data provided in the Atlas of Tehran Metropolis for their own research evaluation and planning.

4.2.1. Geography of Tehran

In order to evaluate Tehran's capability in coping with a potential earthquake disaster, it is first necessary to have a comprehensive overview of the geographic and demographic characteristics of the city. The city of Tehran is spread over an area of 1300 Km2 and is situated in the southern region of the Alborz Mountains. The topography of Tehran consists of mountains, piedmont, and desert. Urban expansion is not possible in the eastern and northern regions of the city due to the steep terrain of the Alborz mountain range. Furthermore, urban expansion is severely limited in the southern region of Tehran due to high groundwater levels and arid zones. Therefore, urban expansion is only feasible in the western region of Tehran. As illustrated in Figure 4-1, Tehran consists of 22 municipal districts which are divided into various administrative centres.

Figure 4-1: Administrative districts of Tehran (Municipality of Tehran, 2009)

Tehran has experienced substantial population growth over the last decade and has become the most populated city in the Middle-East. According to the statistics provided by the 2011 census (Statistical Centre of Iran, 2011), the urban area of Tehran has a population of approximately 10 million inhabitants, while the greater metropolitan area of Tehran has a total population of 12,183,391 inhabitants. As the capital city of Iran, Tehran is also the major hub of political, social and economic activity. Table 4-1 provides insight into Tehran's area, population, and layout of municipal districts.

Table 4-1: Tehran's districts area and population (City Population, 2016)

NAME	COUNTY	AREA	POPULATION	POPULATION DENSITY
DISTRICT 1	Shemiranat County	64.0 km²	379,962	5,936.9/km²
DISTRICT 2	Tehran County	64.0 km²	650,000	10,156.3/km²
DISTRICT 3	Tehran County	31.2 km²	293,181	9,396.8/km²
DISTRICT 4	Tehran County	61.4 km²	864,946	14,087.1/km²
DISTRICT 5	Tehran County	52.9 km²	800,000	15,122.9/km²
DISTRICT 6	Tehran County	21.4 km²	217,127	10,146.1/km²
DISTRICT 7	Tehran County	15.4 km²	309,745	20,113.3/km²
DISTRICT 8	Tehran County	13.4 km²	378,725	28,263.1/km²
DISTRICT 9	Tehran County	19.6 km²	170,000	8,673.5/km²
DISTRICT 10	Tehran County	8.2 km²	320,000	39,024.4/km²
DISTRICT 11	Tehran County	12.6 km²	280,000	22,222.2/km²
DISTRICT 12	Tehran County	16.9 km²	365,000	21,597.6/km²
DISTRICT 13	Tehran County	12.8 km²	275,727	21,541.2/km²

DISTRICT 14	Tehran County	24.3 km²	483,432	19,894.3/km²
DISTRICT 15	Tehran County	35.4 km²	694,678	19,623.7/km²
DISTRICT 16	Tehran County	18.1 km²	332,000	18,342.5/km²
DISTRICT 17	Tehran County	8.2 km²	256,022	31,222.2/km²
DISTRICT 18	Tehran County	37.5 km²	317,110	8,456.7/km²
DISTRICT 19	Tehran County	20.3 km²	249,786	12,304.9/km²
DISTRICT 20	Rey County	23.0 km²	378,445	16,454.1/km²
DISTRICT 21	Tehran County	51.6 km²	157,939	3,060.8/km²
DISTRICT 22	Tehran County	54.0 km²	138,970	2,573.5/km²

Due to its geographic characteristics, Tehran is susceptible to natural disasters such as earthquakes and floods. Tehran also suffers from environmental hazards such as air pollution as a result of excessive road traffic and industrial activity. The substantial amount of industrial activity coupled with Tehran's dense population generates a high risk for accidental disaster. Despite being situated along numerous fault zones, Tehran has not been impacted by a significant earthquake in the last century. However, the city remains highly vulnerable to a high magnitude earthquake.

As determined by Arian et al. (2012), the seven major fault lines located within the geography of Tehran include the North Tehran Fault, Parchin Fault, Kuh-e Sorkh Fault, Mosha Fault, Kahrizak Fault, Pishva Fault, and Garmsar Fault. The Mosha Fault and North Tehran Fault are situated in the northern region of Tehran between the northern mountains and the urban districts which threaten the northern, north-eastern and north-western parts of the city including Districts, 1, 2, 3, 4, 5 and 22 (as highlighted yellow in Figure 4-2). The Kahrizak Fault, Parchin Fault, Pishva Fault, Garmsar Fault and Kuh-e Sorkh Fault are situated in the southern region of Tehran and threaten the southern and south-eastern parts of the city including Districts 15, 16, 19, and 20 (as highlighted blue in Figure 4-2). Hence, the northern and southern regions of the city are those most at risk to the occurrence of an earthquake, followed by the eastern, central and western regions of the city.

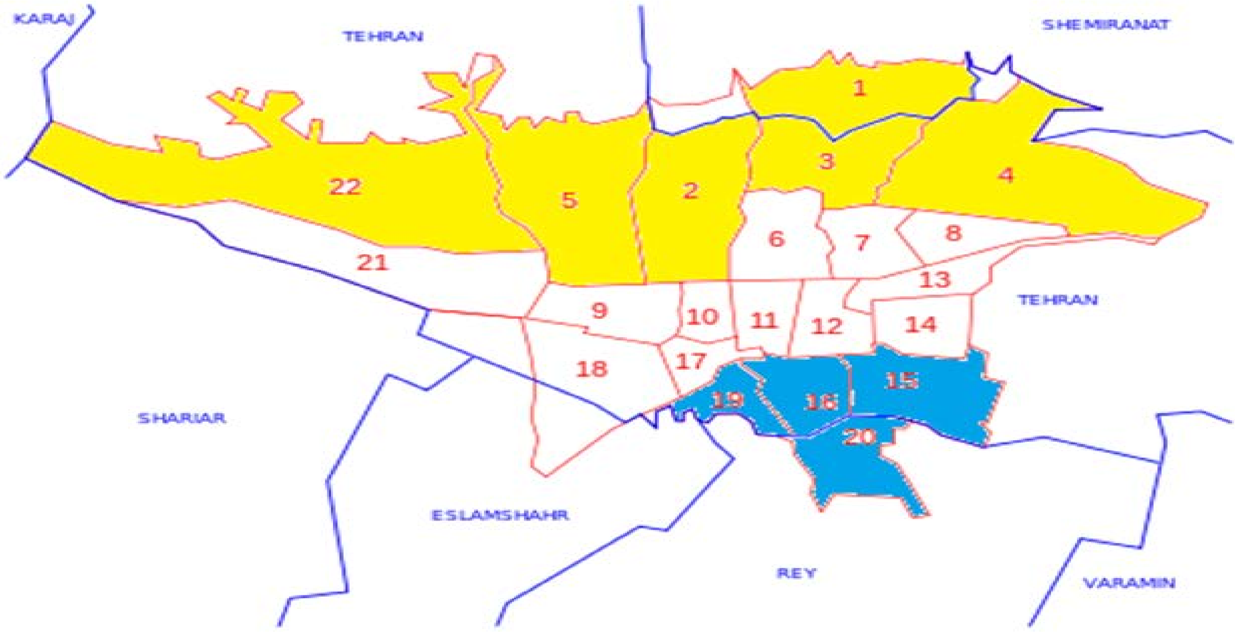


Figure 4-2: Most vulnerable parts of Tehran (Municipality of Tehran, 2009)

4.2.2. Population Distribution in Tehran

In the last five decades from 1966 to 2016, Tehran's population has expanded rapidly to approximately 12 million in 2017, a figure six times higher than that of the population in 1966. Over the last fifty years, the population of Tehran has grown by approximately 10 million inhabitants thereby generating numerous social, economic and environmental consequences. Table 4-2 represents the Tehran's population growth in the last fifty years.

Table 4-2: Population growth of Tehran

YEAR	POPULATION	GROWTH RATE
2016	12183391	-
2006	7711230	1.3
1996	6758845	1.3
1986	6058207	1.3
1976	4530223	2.9
1966	2719730	5.5

As can be observed in Table 4-3, the rate of population growth differs between the various districts of the city. It can be concluded that there has been a trend in inhabitants relocating from the centre of the city to the suburban areas and as a result, central and southern districts such as Districts 9, 13, 15, 16,17,20 and 21 have experienced negative population growth. It may be also observed that District 4 has the overall highest population while District 22 has experienced the most substantial growth in population.

Table 4-3: **Population of the different districts of Tehran** (City Population, 2016)

DISTRICTS	POPULATION				POPULATION GROWTH		
	1976	1986	1996	2006	1976-86	1986-96	1996-06
1	182883	216467	249676	375881	2.8	1.4	4.1
2	220545	269482	458089	607003	3.3	5.3	2.8
3	222007	217084	237301	290272	-0.4	0.9	2.0
4	316904	479512	663166	810548	6.9	3.2	2.0
5	67199	243824	427995	675633	21.5	5.6	4.6
6	231683	258838	220231	236252	1.8	-1.6	0.7
7	327032	302217	300212	309938	-1.3	-0.1	0.3
8	365516	346474	336474	378544	-0.9	-0.3	1.2
9	200867	189805	173482	169988	-0.9	-0.9	-0.2
10	343551	311104	282308	315225	-1.7	-1.0	1.1
11	276712	247927	223965	274650	-1.8	-1.0	2.0
12	301701	230657	189625	246874	-4.5	-2.0	2.6
13	209600	245447	266700	245312	2.6	0.8	-0.8
14	398858	394111	450160	482682	-0.2	1.3	0.7
15	420561	622517	649370	641344	6.5	0.4	-0.1
16	347535	289474	303410	290348	-3.0	0.5	-0.4
17	353428	287367	264300	259857	-3.4	-0.8	-0.2
18	211606	296430	298600	316517	5.6	0.1	0.6
19	140354	216318	227389	245003	7.2	0.5	0.7
20	255653	356079	379750	323716	5.5	0.6	-1.6
21	-	188890	216970	154427	-	1.4	-3.4
22	31162	56020	67230	107130	9.8	1.8	4.7

Figures 4-3 (a), (b), (c) and (d) represent the population distribution among the various age groups in the city. The mean age of Tehran's population is 31.2 years while the active population between the ages of 15-64 is primarily concentrated in the northern parts of the city including Districts 6 and 9. Districts 3 and 6 of northern Tehran contain the highest concentration of the elderly population with ages above 65 years while Districts 18 and 19 of southern Tehran contain the highest concentration of children between the ages of 0-14 years.

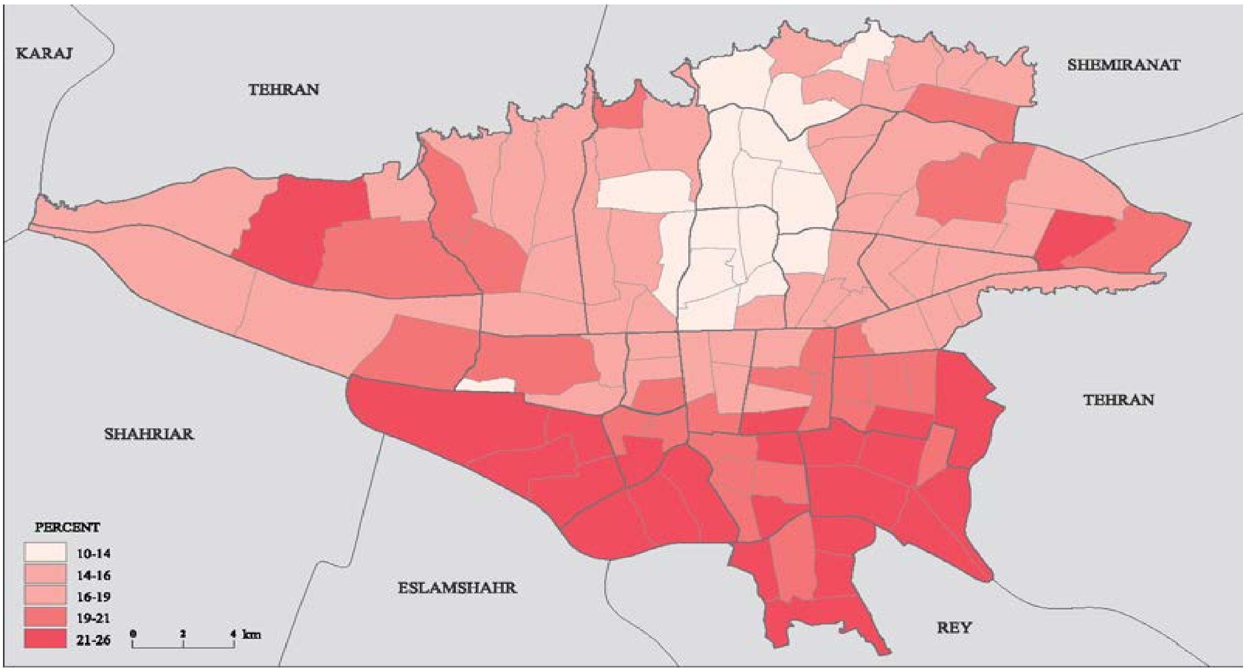


Figure 4-3(a): Population of 0-14 years old (2006)

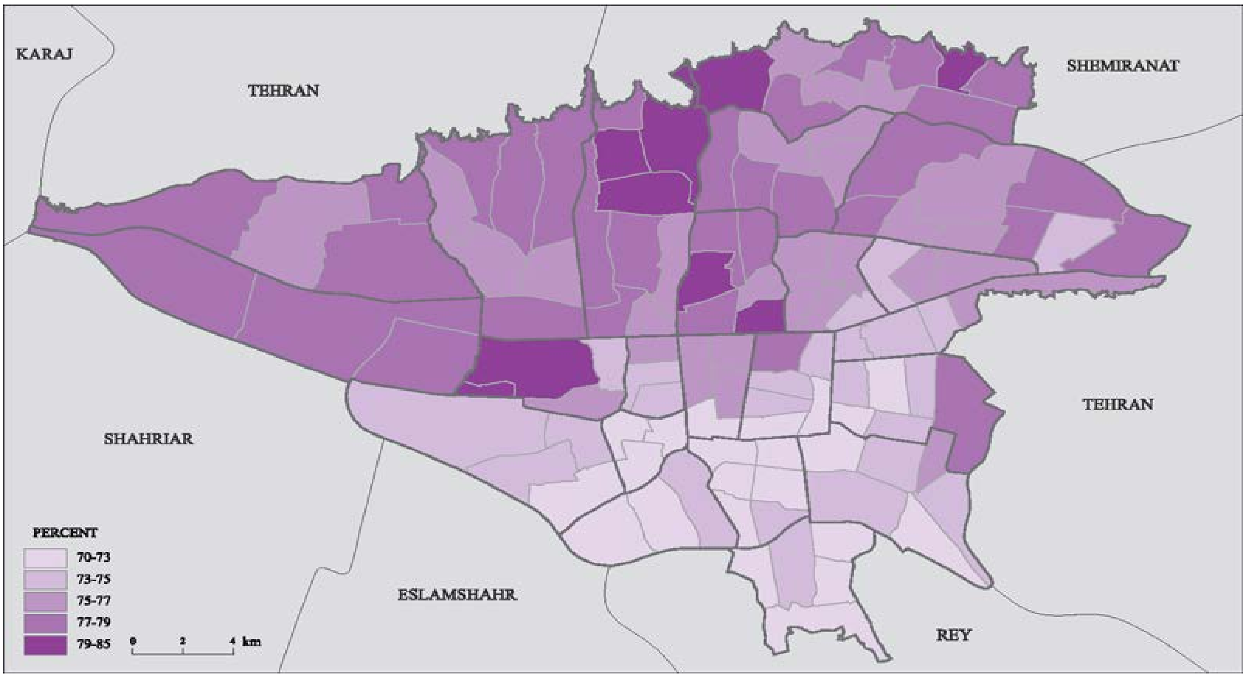


Figure 4-3(b): Population of 15-64 years old (2006)

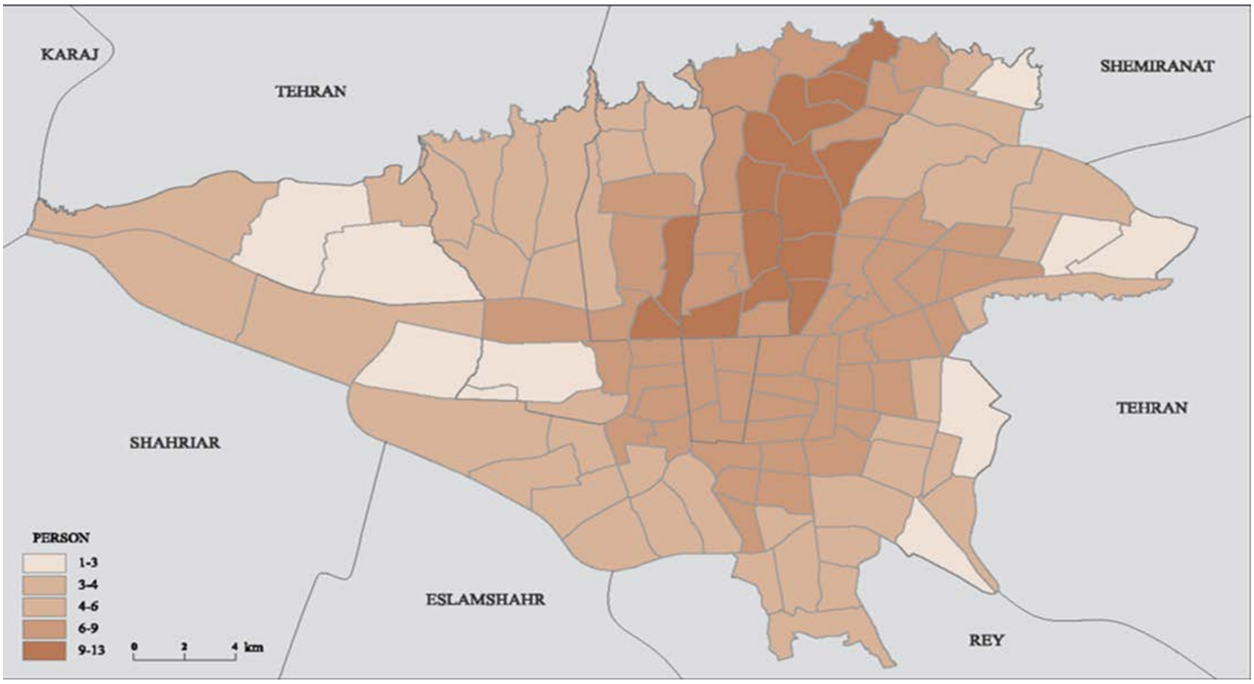


Figure 4-3(c): Population of 65 years old and more (2006)

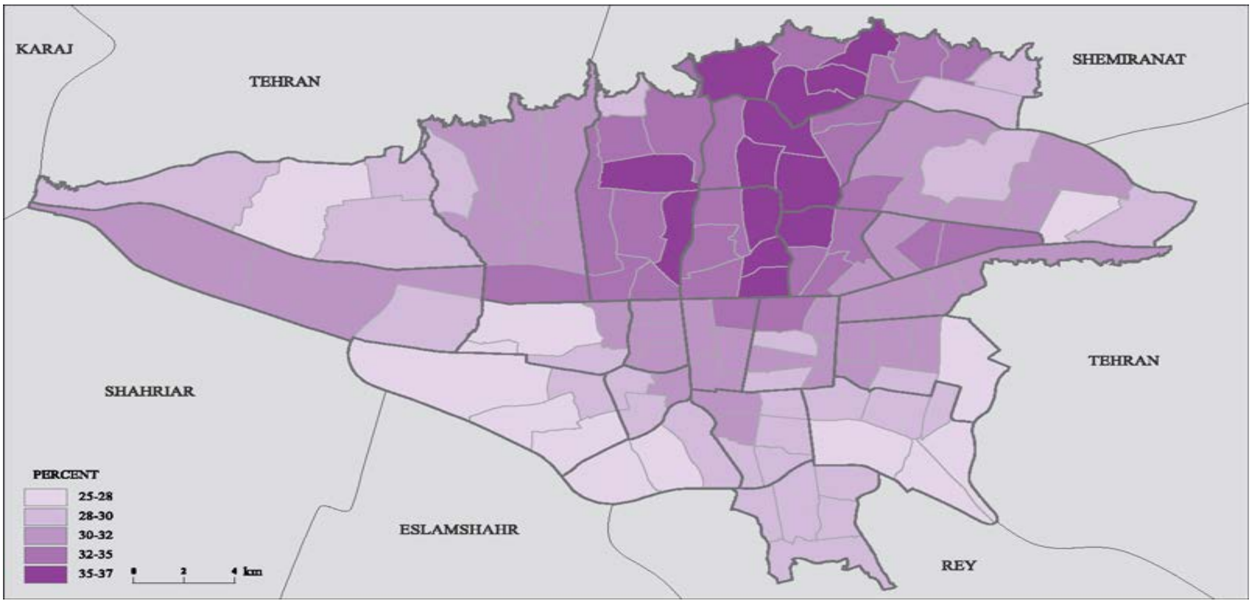


Figure 4-3(d): Population of Average age (2006)

Figure 4-3 (a, b, c, and d): Population distribution of various age groups in Tehran's districts (ATM, 2016)

In all districts, the active population is more than 70% if the total population. The gender ratio for the city of Tehran is 104.4; which is defined as the number of males per every 100 females. As can be observed in Figure 4-4, the gender ratio is not equal among the various districts, with Districts 9, 12 and 14 of central Tehran having the highest gender ratio.

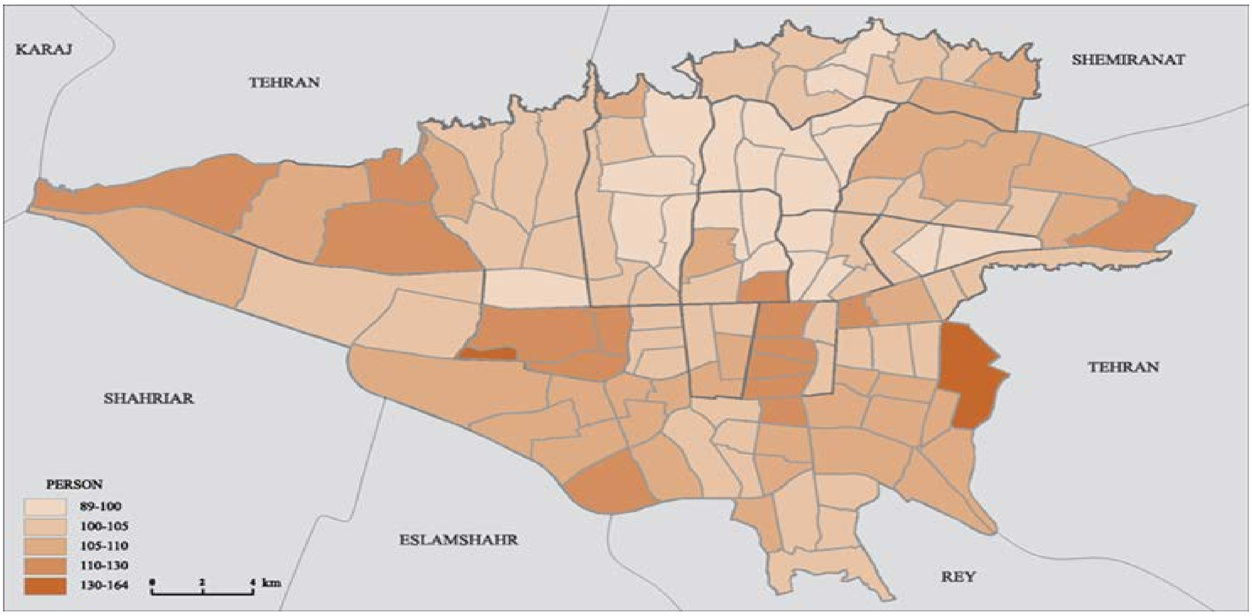


Figure 4-4: Gender ratio in Tehran's districts (ATM, 2016)

Population density is a parameter which has the potential to influence a city's capability to cope with a natural disaster such an earthquake. As illustrated in Figure 4-5, the southern districts of Tehran have the highest population density.

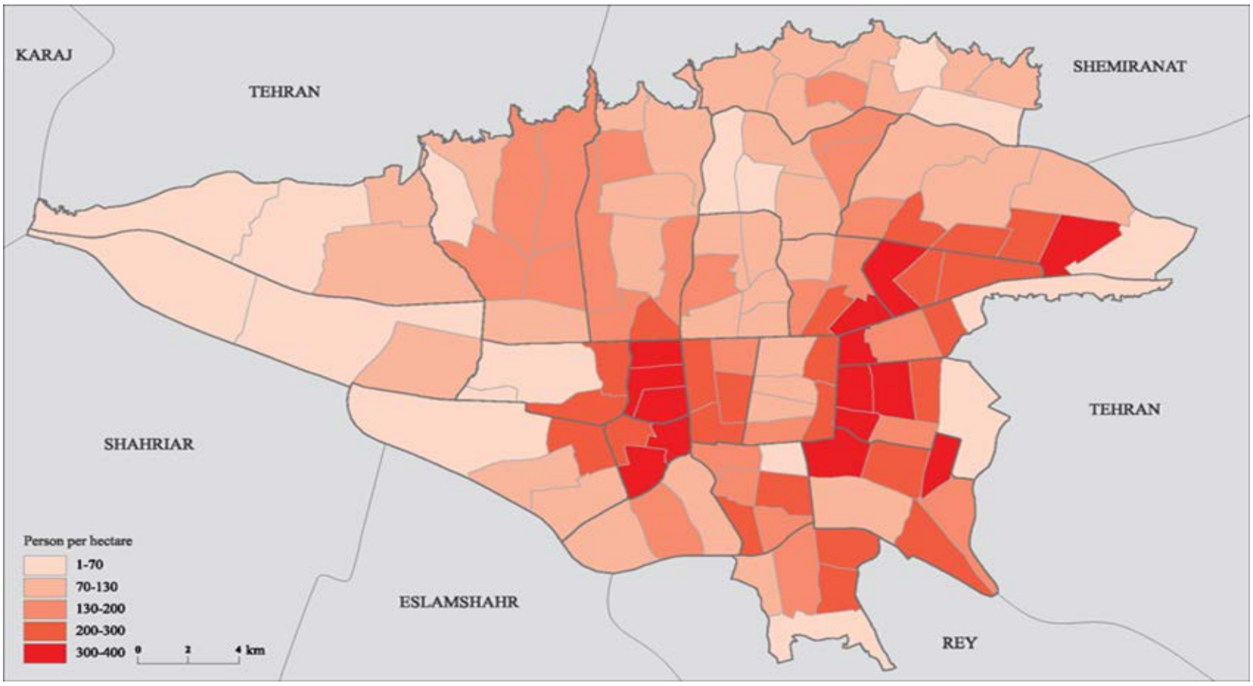


Figure 4-5: Population density in Tehran's districts (ATM, 2016)

4.2.3. Built Environment and Land Use Planning

As illustrated in Table 4-4, Tehran is comprised of several land use categories including residential land use (the most prevalent land use category), commercial land use, administrative and governmental land use, and green areas.

Table 4-4: **Occupied area and proportion of type of land used** (ATM, 2016)

No.	Type of Land Use	Occupied Area Km^2	Percent
1	Residential	177	28.8
2	Commercial-administrative	26	4.2
3	Industrial-manufactory	27	4.4
4	Transportation and warehousing	30	4.9
5	Passway and access network	114	18.6
6	Urban services	50	8.1
7	Green space	70	11.4
8	Agriculture	35	5.7
9	Military	44	7.2

As illustrated in Figure 4-6, Tehran contains a wide spectrum of urban texture typologies including historic buildings, modern buildings, and rural buildings.

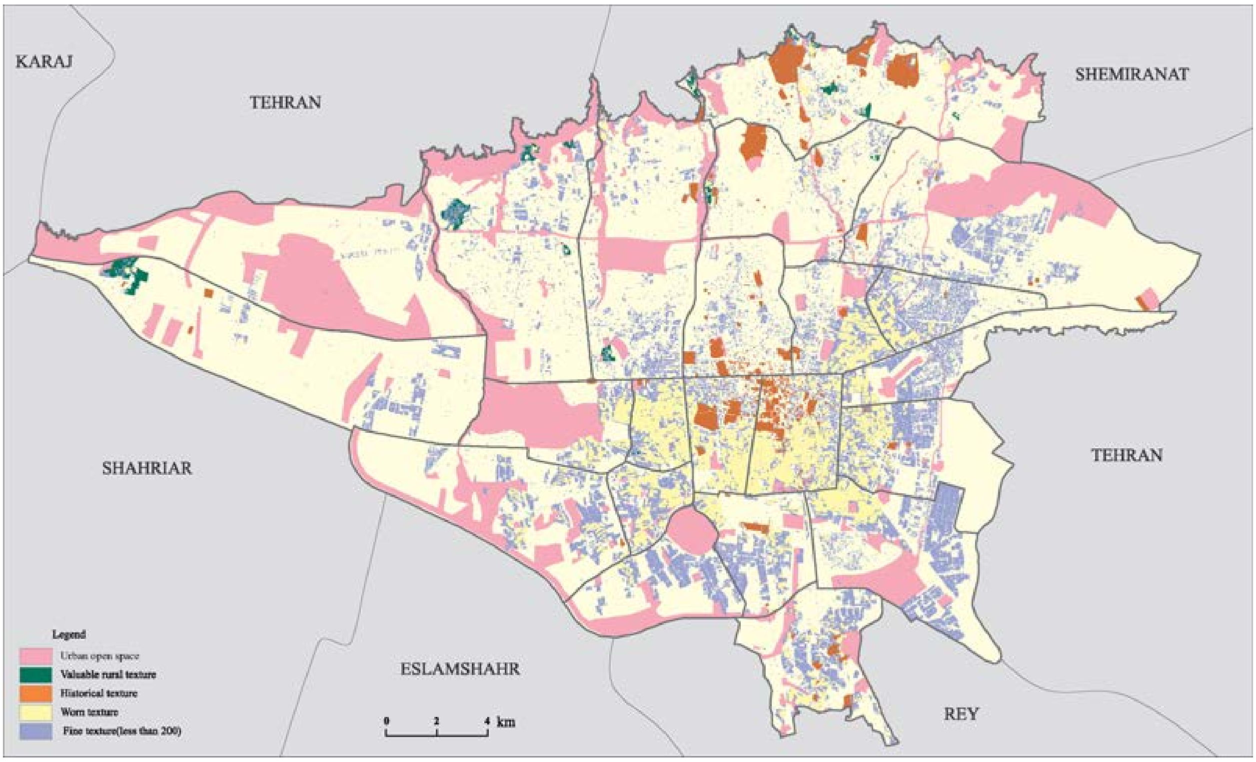


Figure 4-6: Urban Texture typology (ATM, 2016)

Pertaining to the ongoing development of Tehran, the highest concentration of recent construction can be found in the north-western districts including Districts 2 and 5, north-eastern districts including Districts 4 and 8, south-western districts including District 18, and south-eastern districts including Districts 14 and 15 (see Figures 4-7a and 4-7b). Furthermore, District 1 in the north and District 8 in the east have been developed in a manner which is in stark contrast to the older parts of the city in terms of their construction pattern and resident demographics. In these districts, the streets are wider, the buildings more contemporary in design, and the height of buildings greater than of those in other districts.

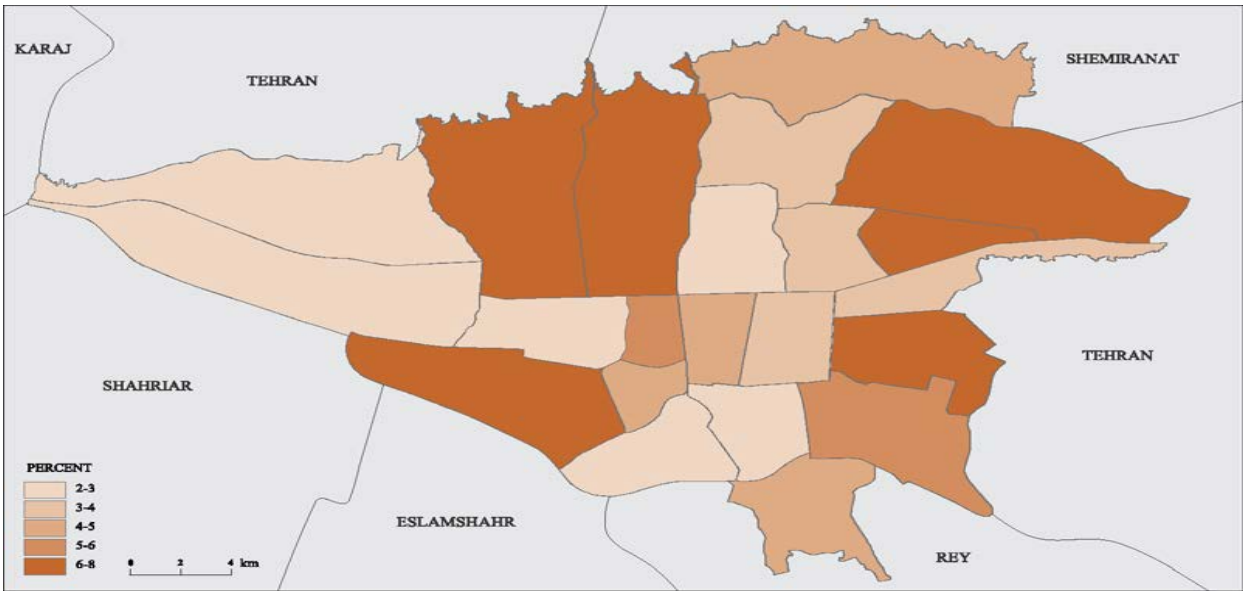


Figure 4-7 (a): Building Permit Issued (2006-2010)

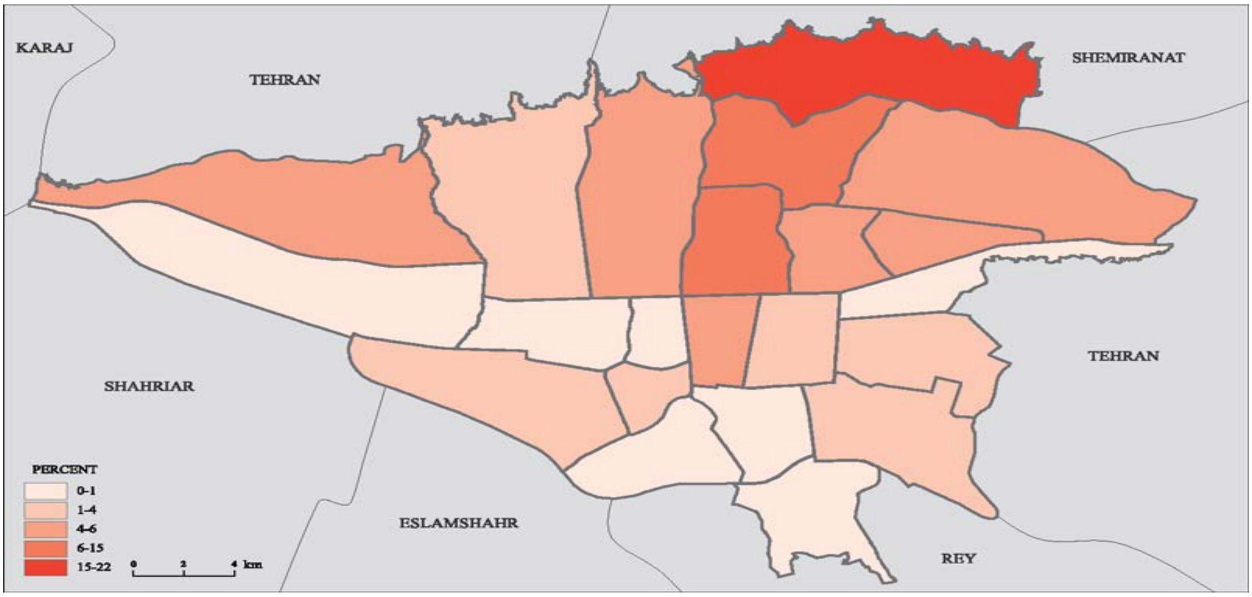


Figure 4-7 (b): Building Permit Issued for Building Over 10 Floors (2000-2001)

Figure 4-7(a and b): City development and building construction in Tehran's districts (ATM, 2016)

There are a high number of vulnerable buildings in Tehran which remain under significant threat in the event of an earthquake due to either their unstable structure or their inaccessibility due to narrow roadways. Table 4-5 shows the proportion of vulnerable areas throughout the various districts of the city.

Table 4-5: Portion and rate of worn textures in various district of Tehran (ATM, 2016)

District	District Area (H.)	Worn Texture (H.)	Worn Texture (%)	District	District Area (H.)	Worn Texture (H.)	Worn Texture (%)
1	4574.24	64.28	1.4	**12**	1600.81	592.65	37.0
2	4761.00	18.65	0.4	**13**	1700.01	73.04	4.3
3	2938.27	24.54	0.8	**14**	2412.42	257.54	10.7
4	6160.29	7.72	0.1	**15**	3130.31	246.28	7.9
5	5321.81	11.58	0.2	**16**	1652.14	149.11	9.0
6	2141.26	5.07	0.2	**17**	821.69	239.88	29.2
7	1536.54	237.48	15.5	**18**	3807.98	102.82	2.7
8	1322.12	143.85	10.9	**19**	2053.37	22.36	1.1
9	1951.44	146.03	7.5	**20**	2254.89	137.23	6.1
10	807.25	146.03	18.1	**21**	5549.90	6.92	0.1
11	1204.97	352.35	29.2	**22**	5851.09	0.95	0.0

Table 4-6 and Figure 4-8 indicate that the distribution of built and open spaces has not been equally proportioned among the various districts in Tehran. As can be observed in the table and the figure, suburban areas such as District 22 have the highest proportion of green areas, public spaces and broad roadways. While central area such as District 10, 11, 12, and 17 have the lowest proportion of green areas, public spaces and broad roadways.

Table 4-6: Green, public spaces, and streets compared with built-up areas in Tehran's districts (ATM, 2016)

DISTRICT	AREA	BUILT-UP AREAS		OPEN SPACES		BUILT / OPEN RATIO	DISTRICT	AREA	BUILT-UP AREAS		OPEN SPACES		BUILT / OPEN RATIO
		H.	%	H.	%				H.	%	H.	%	
1	4574	3388	1.74	1186	9.25	9.2	**12**	1600	1313	82.0	288	18.0	4.6
2	4761	3341	2.7	1420	8.29	2.4	**13**	1700	1349	79.4	351	20.6	3.8
3	2938	2095	3.71	844	7.28	2.5	**14**	2412	2064	85.6	348	14.4	5.9
4	6160	3884	0.63	2277	0.37	1.7	**15**	3130	2182	69.7	948	30.3	2.3
5	5321	3118	6.58	2204	4.41	1.4	**16**	1652	1265	76.5	388	23.5	3.3
6	2141	1611	2.75	531	8.24	3.0	**17**	821	689	83.8	133	16.2	5.2
7	1536	1284	6.83	252	4.16	5.1	**18**	3807	2744	72.1	1064	27.9	2.6
8	1322	1081	8.81	241	2.18	4.5	**19**	2053	1334	56.0	719	35.0	1.9
9	1951	698	8.35	1253	2.64	0.6	**20**	2254	1208	53.6	1047	46.4	1.2
10	807	609	4.75	198	6.24	3.1	**21**	5549	3923	70.7	1627	29.3	2.4
11	1204	889	8.73	316	26.2	2.8	**22**	5851	2580	44.1	3271	55.9	0.8

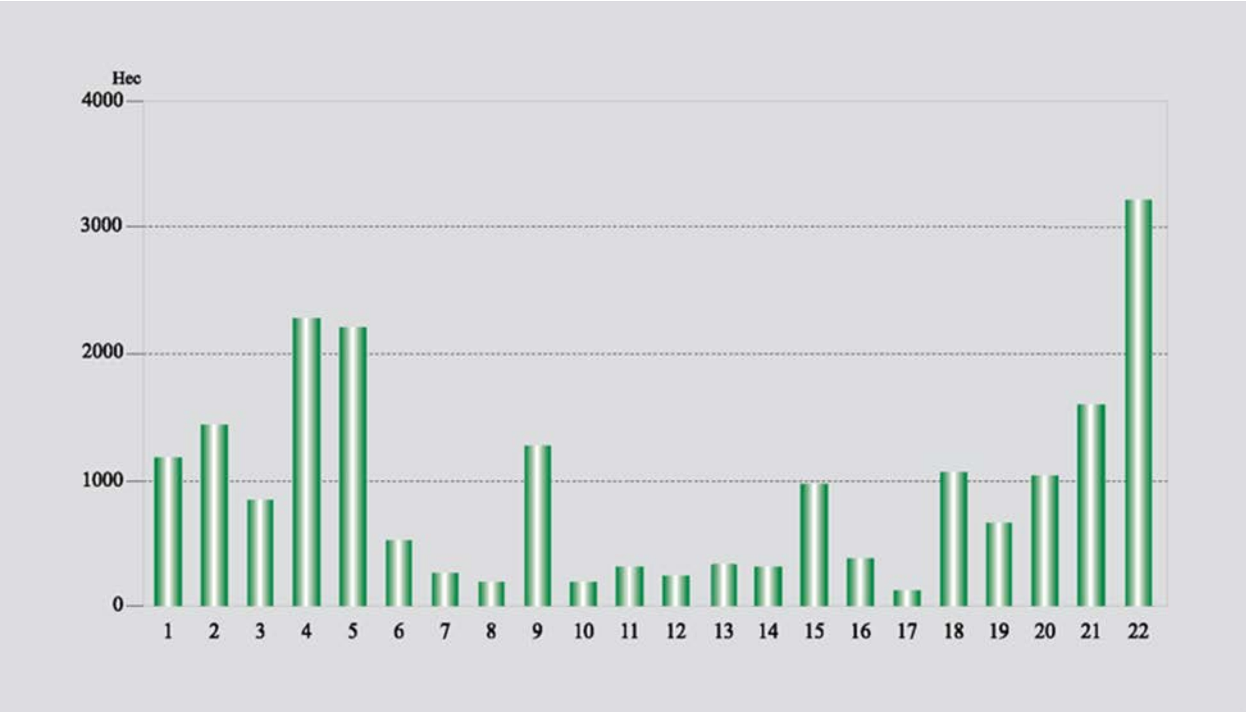


Figure 4-8: **Open public spaces, green spaces, and streets** (ATM, 2016)

The proportion of public and open spaces between Tehran’s 22 districts can be observed in Figure 4-9.

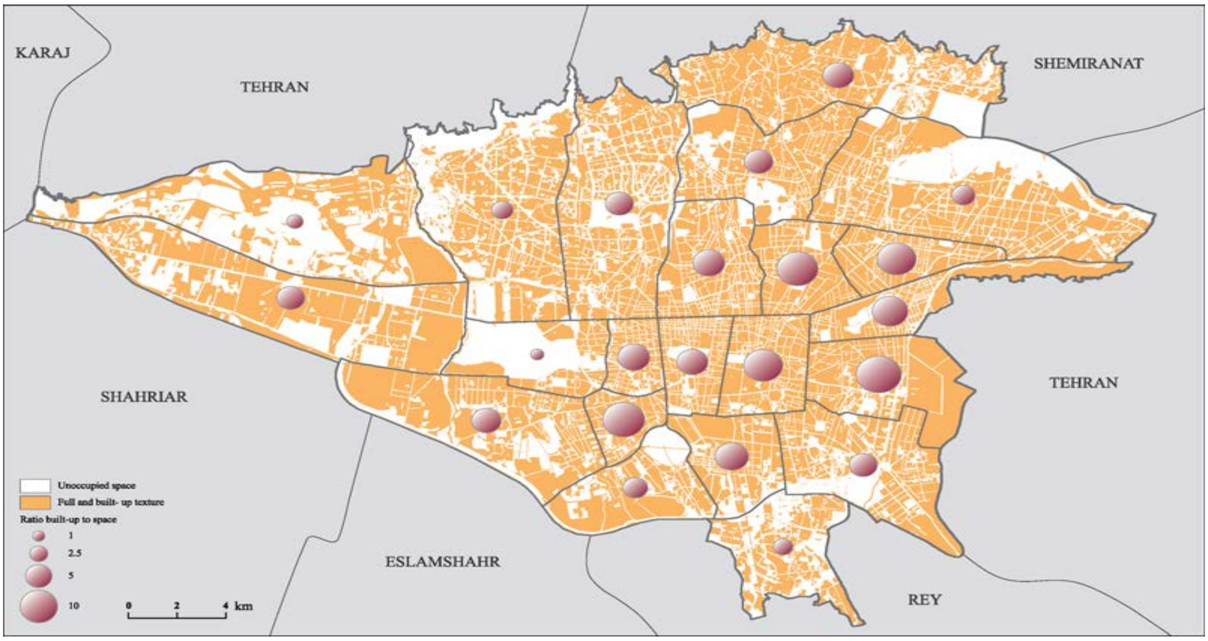


Figure 4-9: Situation and degree of public open spaces in the areas (ATM, 2016)

The quality of access to various urban services and facilities including emergency, health, and treatment, educational, transportation, cultural and recreation is shown in Figure 4-10 (a), (b), (c), (d), and (e). As could be seen in this figure, the internal and central districts of Tehran have better access to urban facilities than districts located in the western and suburban parts of the city. It is to be noted that the quality of access to urban services such as healthcare and emergency services has a direct impact upon the vulnerability of a city and the success of earthquake risk reduction models.

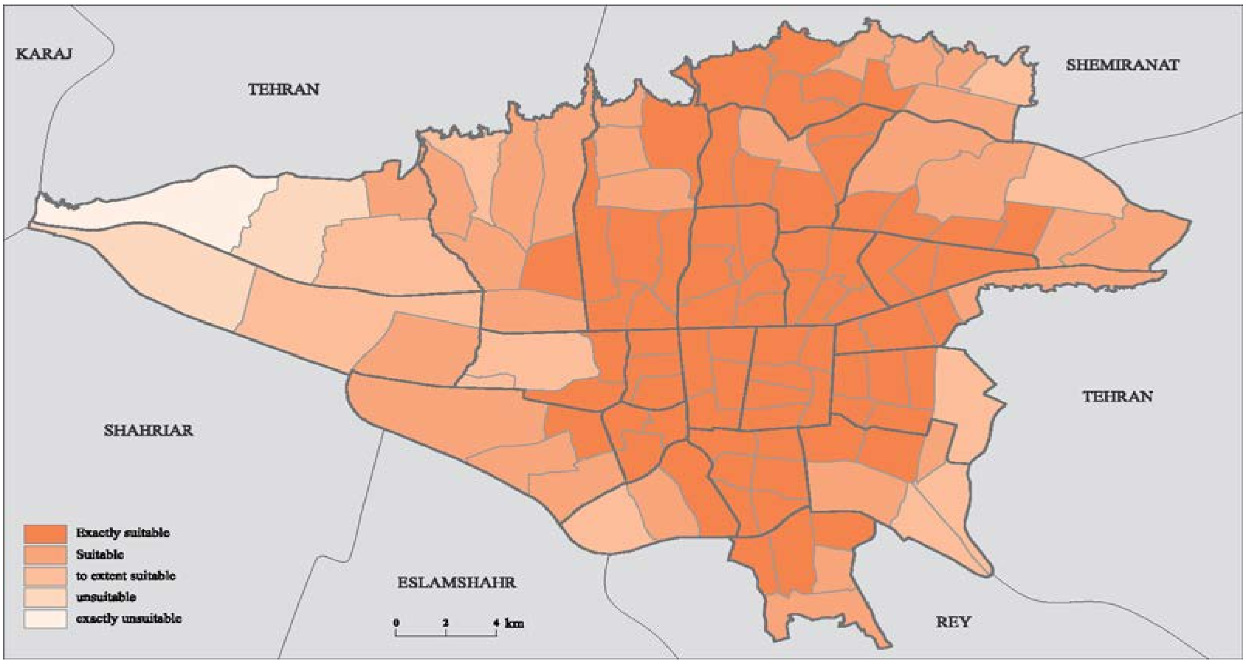


Figure 4-10 (a): The quality of access to urban services (2006)

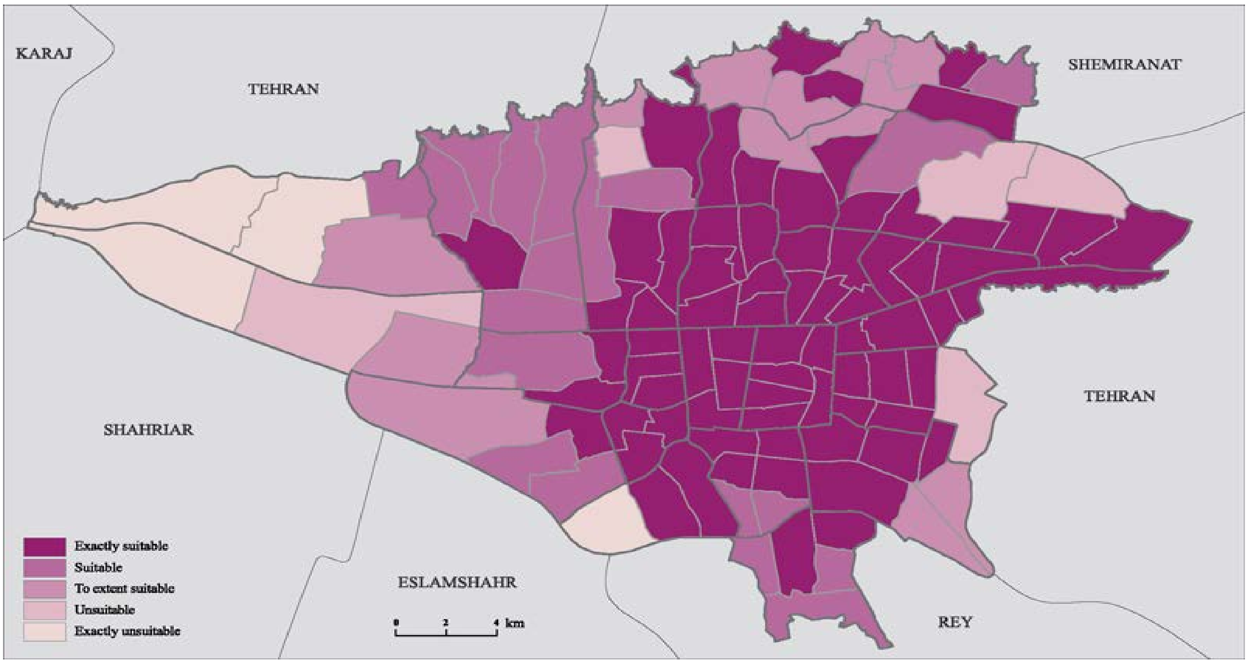


Figure 4-10 (b): The quality of access to emergency services (2006)

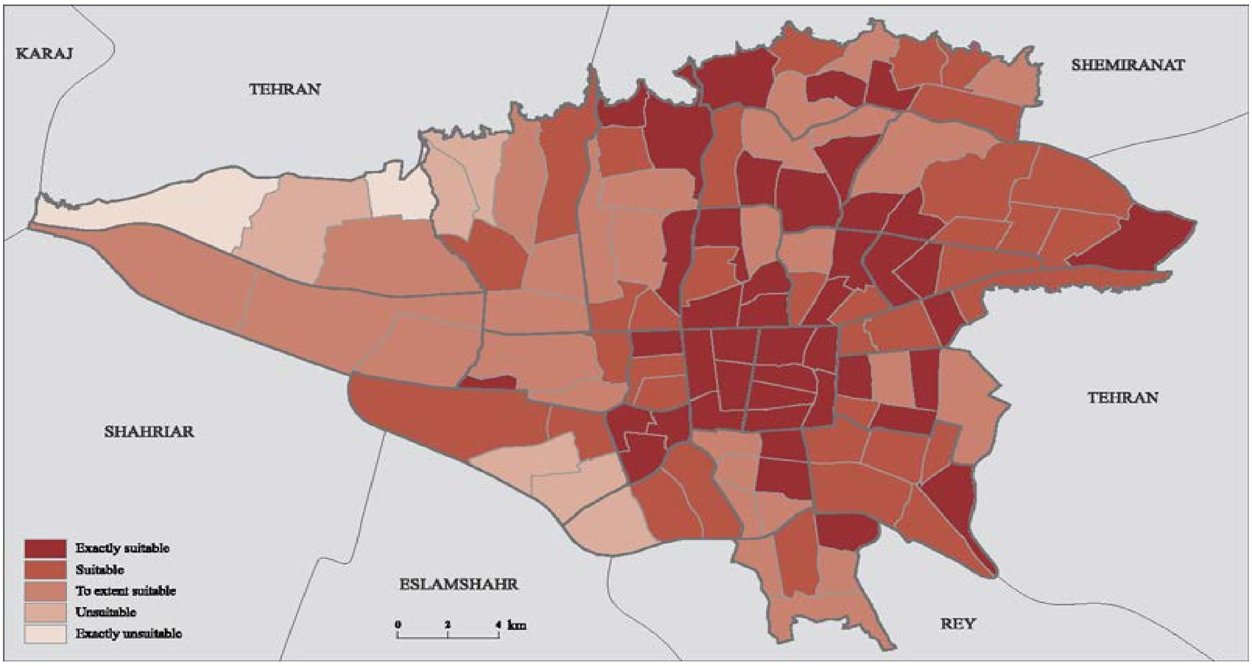


Figure 4-10 (c): The quality of access to fire station (2006)

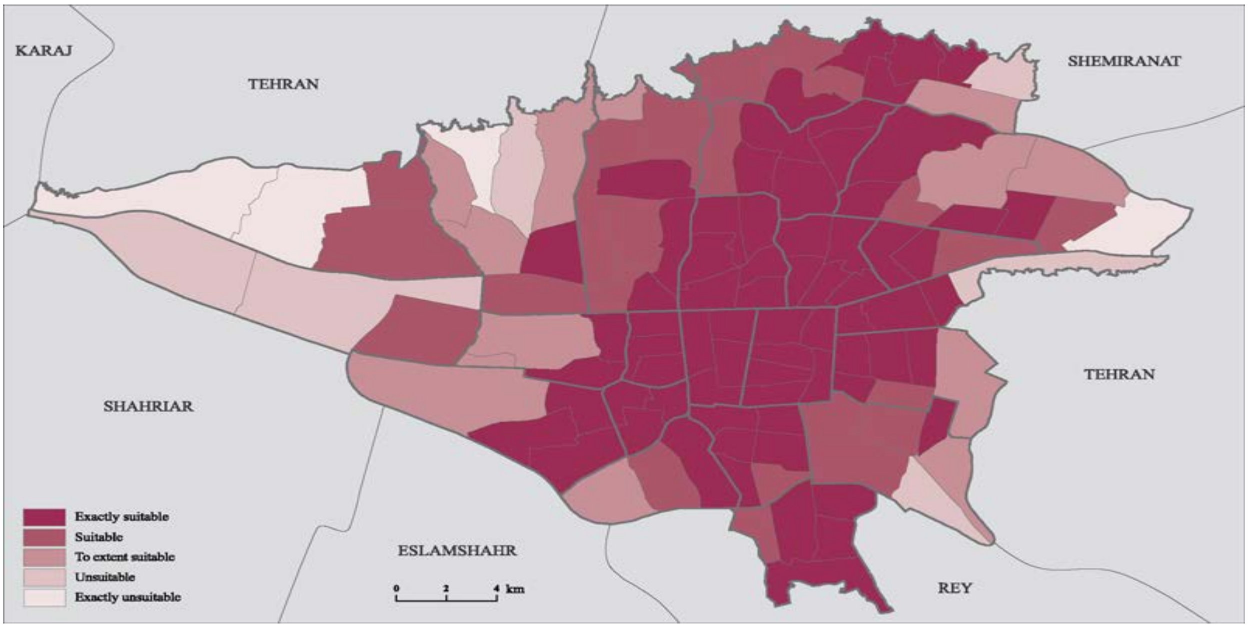


Figure 4-10 (d): The quality of access to hospitals (2006)

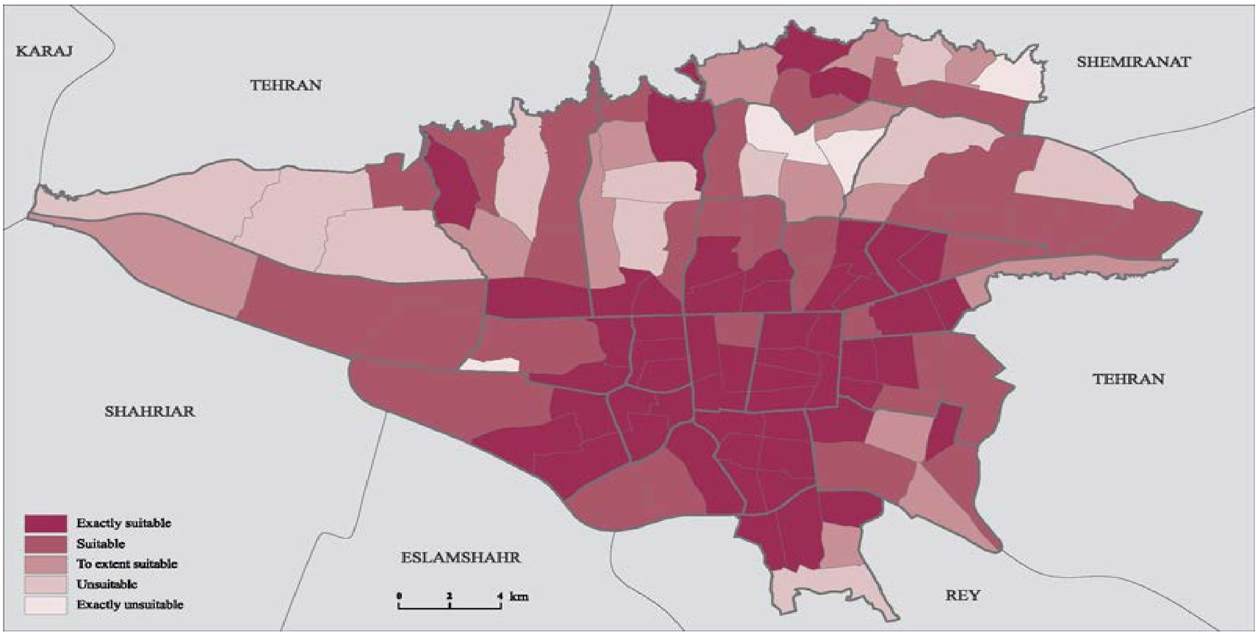


Figure 4-10 (e): The quality of access to health care services (2006)

Figure 4-10 (a, b, c, d, and e): The quality of access to urban services and facilities of Tehran's districts (ATM, 2016)

The quality of building's structure and construction materials represent the overall quality of the residential or commercial units which are delivered to the end user. According to this parameter, Tehran's buildings are classified into three categories: 1) durable buildings, which are constructed of reinforced concrete and metal frames; 2) semi-durable buildings, which are constructed of unreinforced masonry (URM); and 3) low-quality buildings which may be constructed with any combination of unreinforced semi-metal frames, steel beams, bricks, stone or wood (Ghafory-Ashtiany, 1999). Results obtained through studied conducted by numerous researchers (e.g., Zolfaghari, 2006; Naderzadeh and Moinfar, 2004; Ghafory-Ashtiany, 1999) show that over seventy percent of buildings in Tehran are either unreinforced masonry (URM) buildings or constructed of semi-metal frames which fall into the low-quality building category. Figures 4-11a, 4-11b and 4-11c illustrate the ratio of buildings constructed of metal, concrete or brick within Tehran.

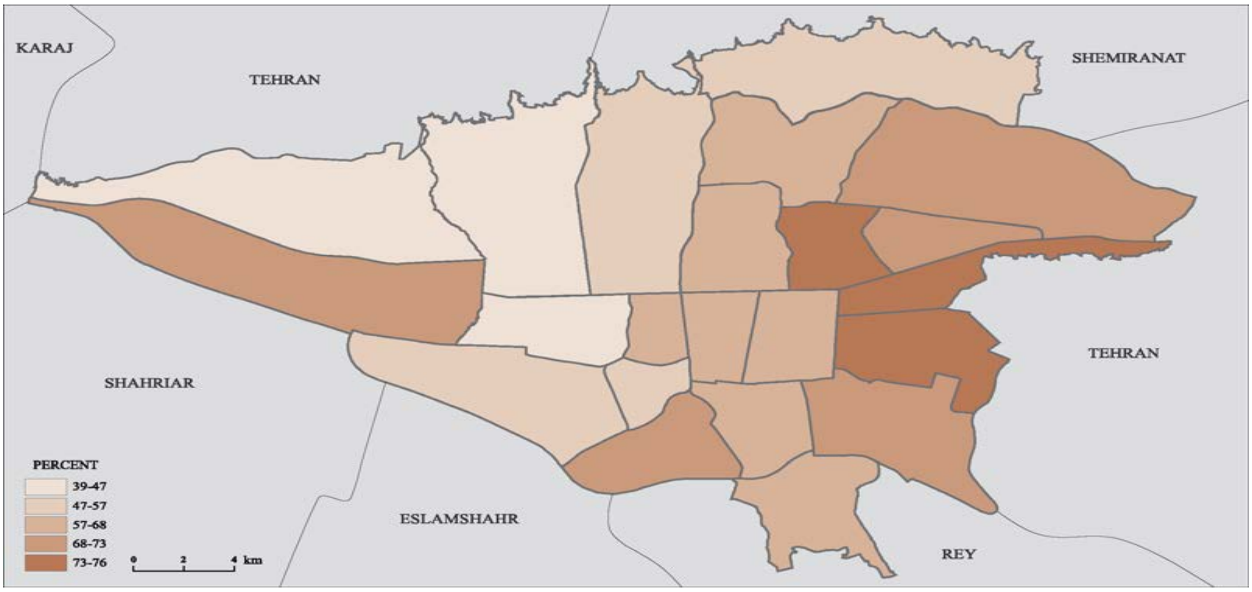


Figure 4-11 (a): residential Units with Metal Structures (2006)

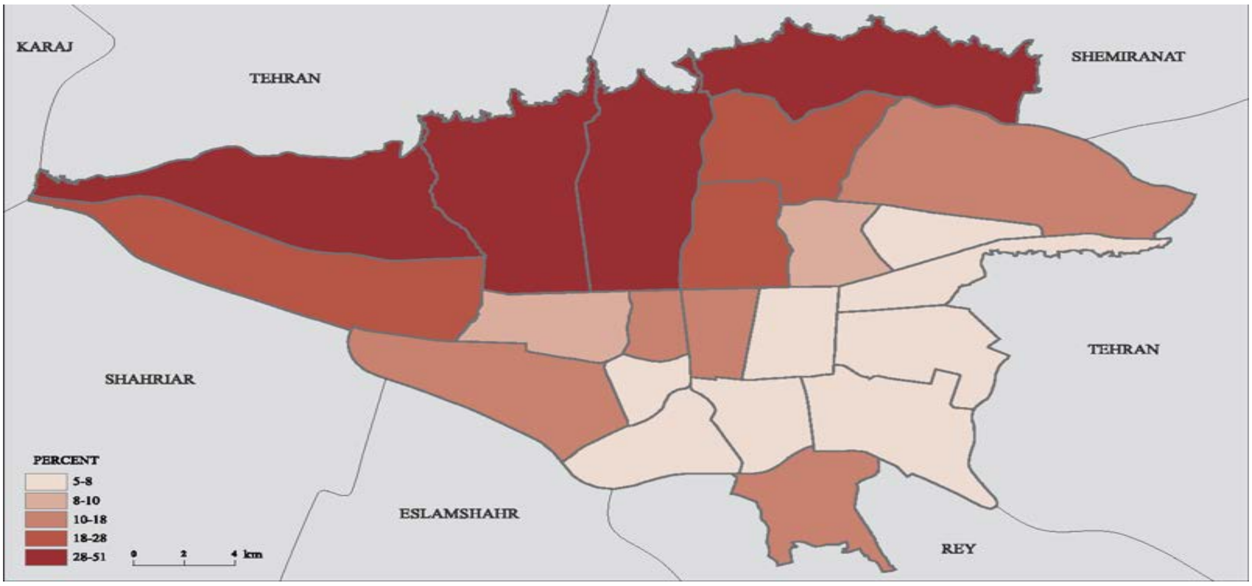


Figure 4-11 (b): residential Units with Concrete Structures (2006)

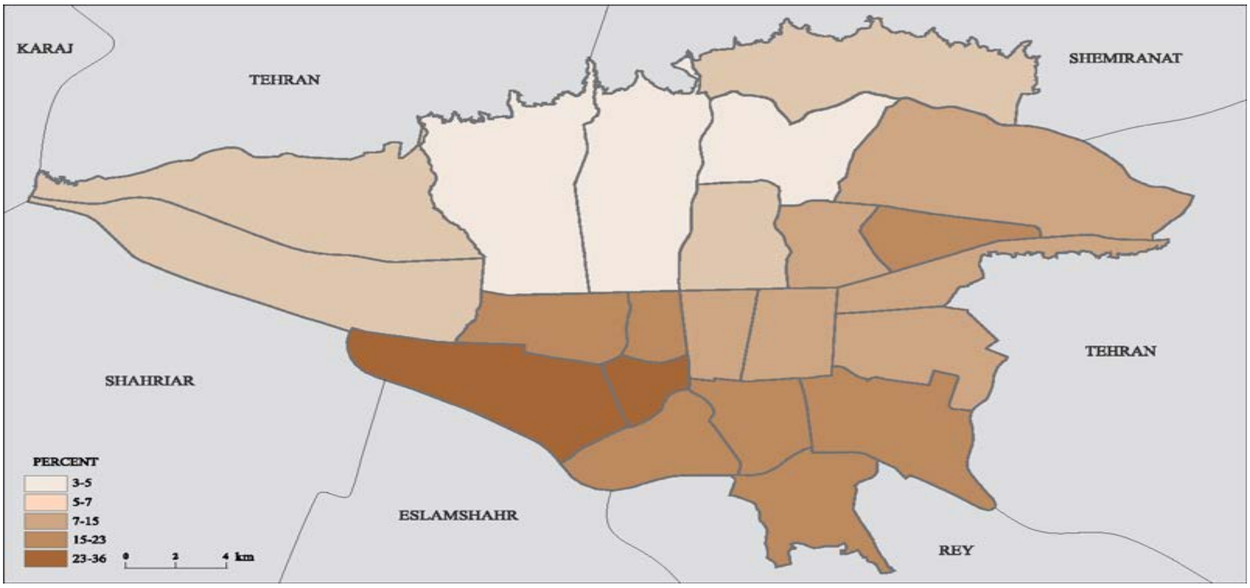


Figure 4-11 (c): residential Units with Metal and Brick Structures (2006)

Figure 4-11 (a, b, and c): The quality of structures in different Tehran's district (ATM, 2016)

As previously discussed in chapter two, the age of buildings also is a key factor in earthquake vulnerability. The International Cooperation Agency (JICA) and the Centre for Earthquake and Environmental Studies of Tehran (CEST) report that 16% of buildings in Tehran were constructed before 1966, 19% of buildings in Tehran were constructed between 1966-1975, 42% of buildings in Tehran were constructed between 1976-1988, and less than 23% of buildings in Tehran were constructed after 1988 (JICA, 2000). The statistics presented in Figures 4-12a, 4-12b, 4-12c, and 4-12d indicate that the central and southern districts of Tehran contain a high number of older buildings being greater than thirty years of age.

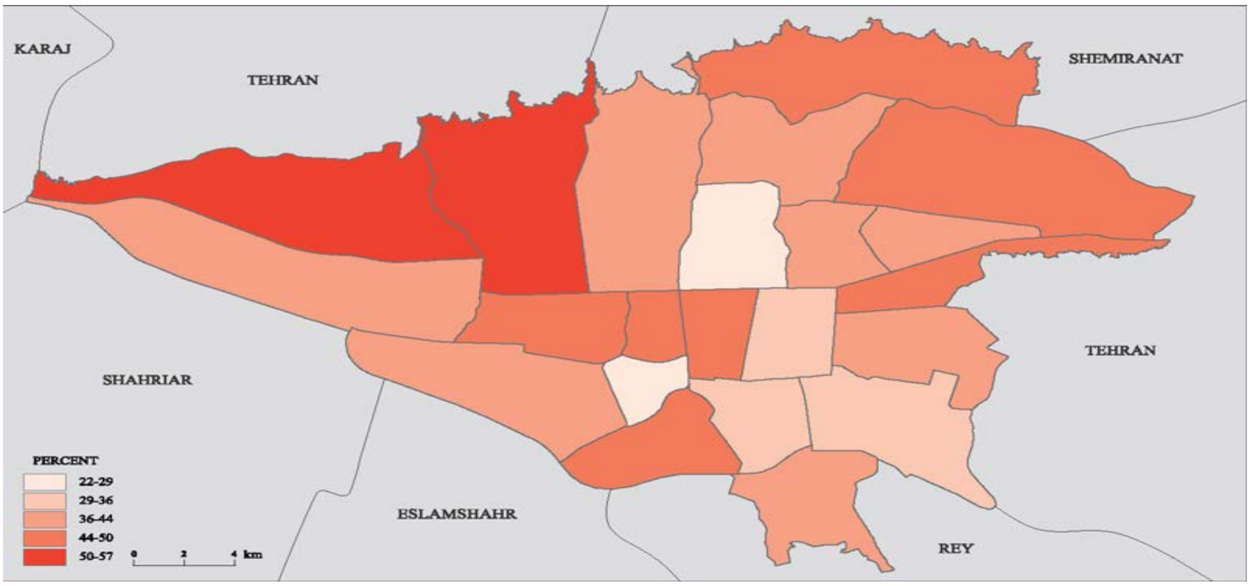


Figure 4-12 (a): Residential Units of 10 years old and less (2006)

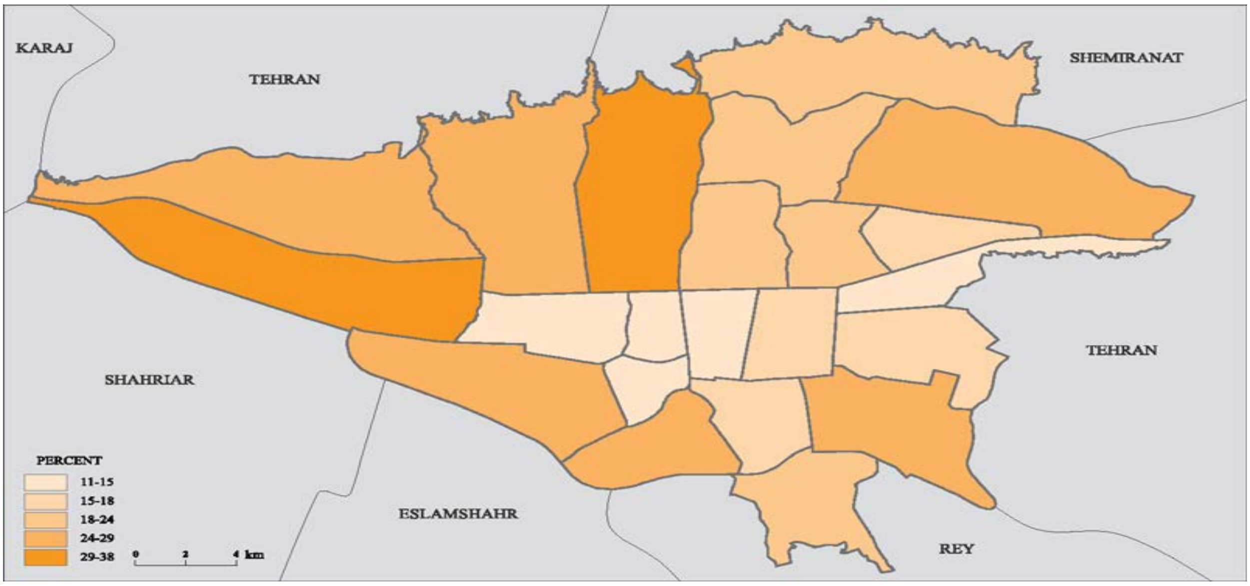


Figure 4-12 (b): Residential Units of 20 years old (2006)

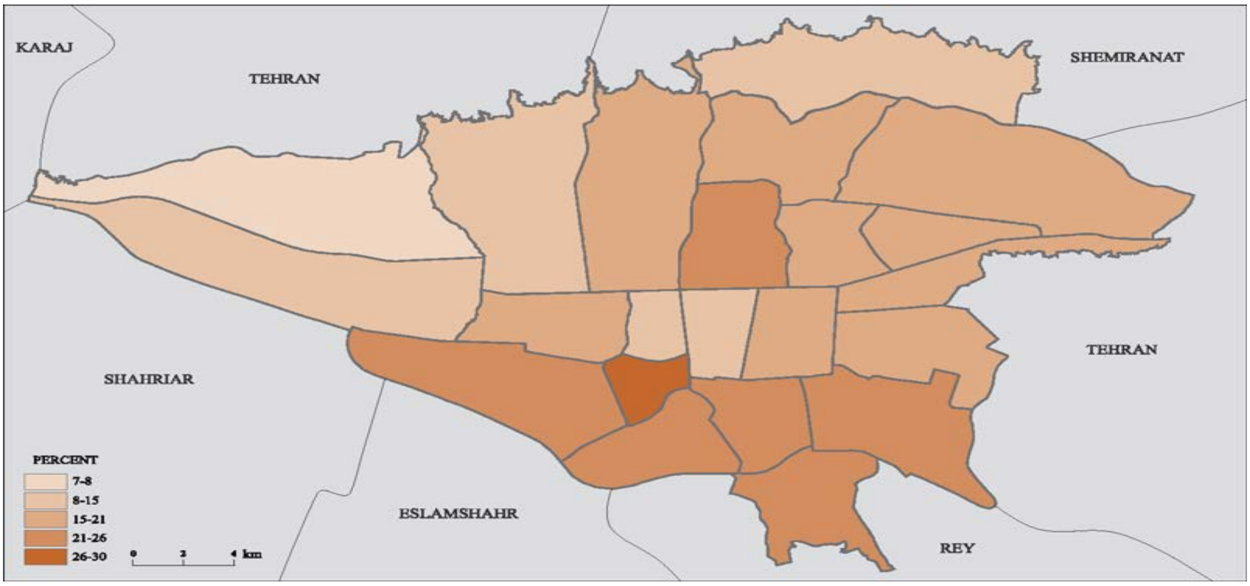


Figure 4-12 (c): Residential Units of 30 years old (2006)

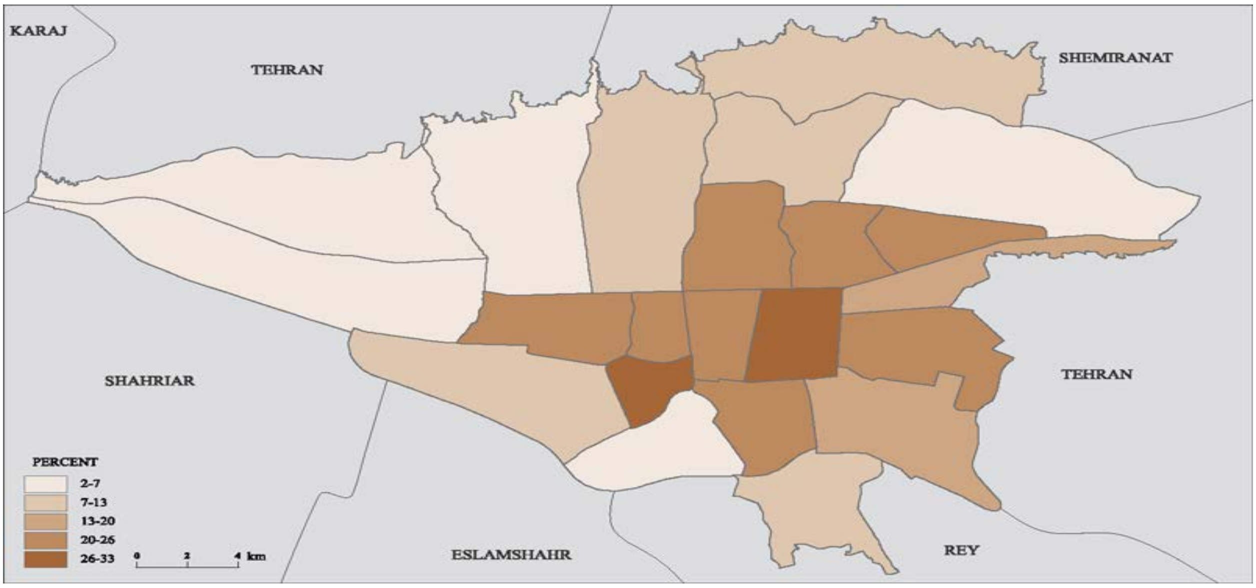


Figure 4-12 (d): Residential Units over 30 years old (2006)

Figure 4-12(a, b, c and d): The age of buildings across Tehran's districts

4.3. Quantitative Data Analysis: Questionnaire

The research data collected through questionnaire is analysed using the descriptive analysis technique and presented via Microsoft Excel spreadsheets, graphs, and charts. As explained in Chapter Three, the questionnaire which has been developed to address the research questions was distributed among 384 respondents. Map of Tehran's metropolitan area and the 22 Districts where studies have been conducted are shown in Figure 4-13.

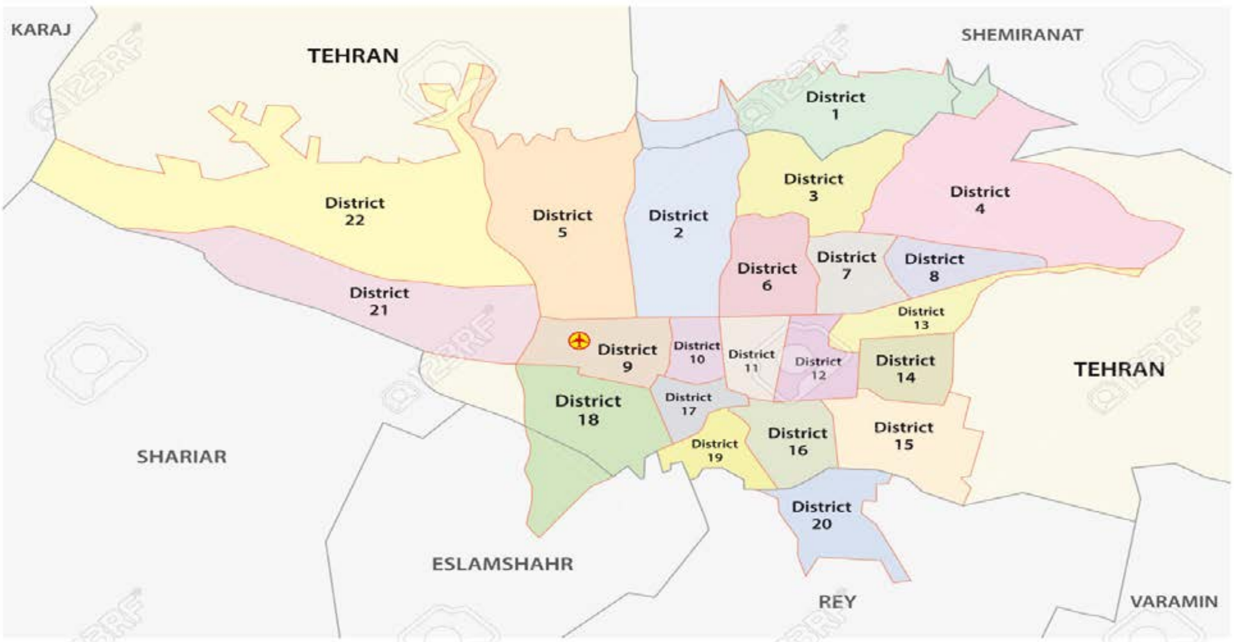


Figure 4-13: Distribution of the participants in the study area

Of the 384 respondents selected, 330 respondents successfully returned the questionnaire to the researcher. Hence, a total number of 54 respondents failed to either return the questionnaire or answer above 50% of the research questions thereby invalidating the questionnaire. The survey response rate totalled 86%; which is defined as the number of persons successfully surveyed versus the number of persons presented with the surveyed,

The American Association for Public Opinion Research (AAPOR) accepts several different methods for measuring response rates, however, they request that the researcher disclose the methods by which response rates have been measured in their research (AAPOR, 2016). As it is generally preferable to attain a response rate of ≥ 80% (AAPOR, 2016), we can, therefore, grant that the response rate achieved is acceptable for the purposes of this research. The results obtained from the questionnaire are presented in this section in the form of Microsoft Excel spreadsheets and pie charts. The author has selected these methods of presentation to enable readers to gain a clear understanding of the responses obtained from numerous participants provided with uniform questions.

4.3.1. Part 1: Demographic Information

This section examines the participants' personal profile, which consists of information such as age group, gender, level of education, working region, and the number of years operating within their current working region. Demographic information is essential as it assists the researcher to identify certain parameters which may affect the results. In addition, the gender ratio of the respondents is calculated in order to gain a perspective into the earthquake preparedness of Tehran's construction practitioners between the male and female survey respondents. As illustrated in Figure 4-14, male respondents constituted a majority of the survey demographic with a total number of 251 persons or 76% of the survey demographics, while female respondents constituted a lower proportion of the survey demographic with only 79 persons or 24% of the total survey population. This gender ratio indicates that there are a greater number of males active within Tehran's construction engineering community versus females and highlights the proportional capacity of the two genders to influence the level of Tehran's seismic resilience.

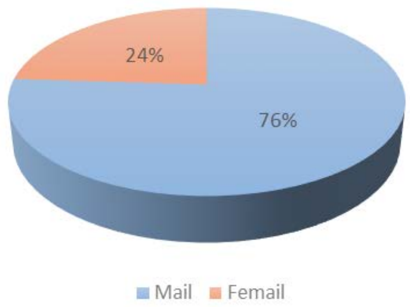


Figure 4-14: Gender of the participants in the study

Figure 4-15 illustrates that 43% of respondents are within the age group of 30-39, while 27.5% of the respondents are between 40-49 years of age. These figures highlight that the majority of survey participants are between the ages of 30-50, and reflects upon the modal average age groups within Tehran's construction engineering community.

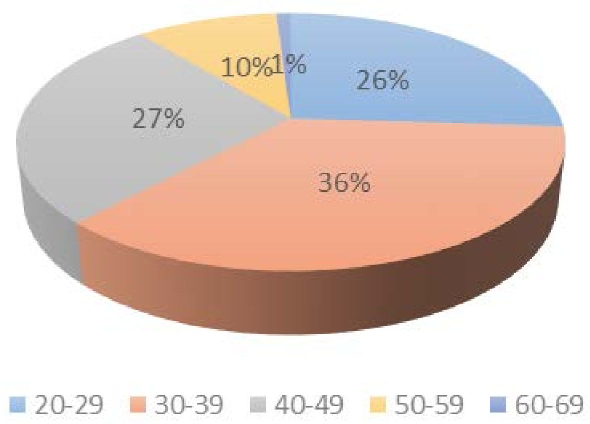


Figure 4-15: Age group of the participants in the study

Construction practitioners within this age range of 30-50 years, based upon their era of education, are expected to be aware of the latest construction design and practice standards relative to seismic codes as prescribed in the Iranian Seismic Code (2800) as endorsed by the Islamic Republic of Iran government and officially implemented in 1988 (Building & Housing Research Center, 2007). Engineers' awareness of construction codes relative to the design and construction of seismic resistant buildings is an essential factor in the reduction of earthquake hazard impacts by improving the types of structures built and the quality of construction materials used during construction. Although construction engineers may participate in a wide spectrum of earthquake engineering disciplines, their particular skill set, and knowledge is often limited to a specific specialization. Therefore, engineers within each particular discipline must be kept continuously aware of the latest earthquake engineering technologies and the methods by which to implement these technologies within their fields (Lawlor, 2013). The awareness of engineers of the most recent technologies in seismic engineering is an important factor of earthquake risk reduction within built environments.

Figures 4-16 and 4-17 illustrate the educational qualification and professional membership of the survey respondents. These figures indicate that a majority of respondents, approximately 70%, do not hold any membership with professional institutes or societies of engineering.

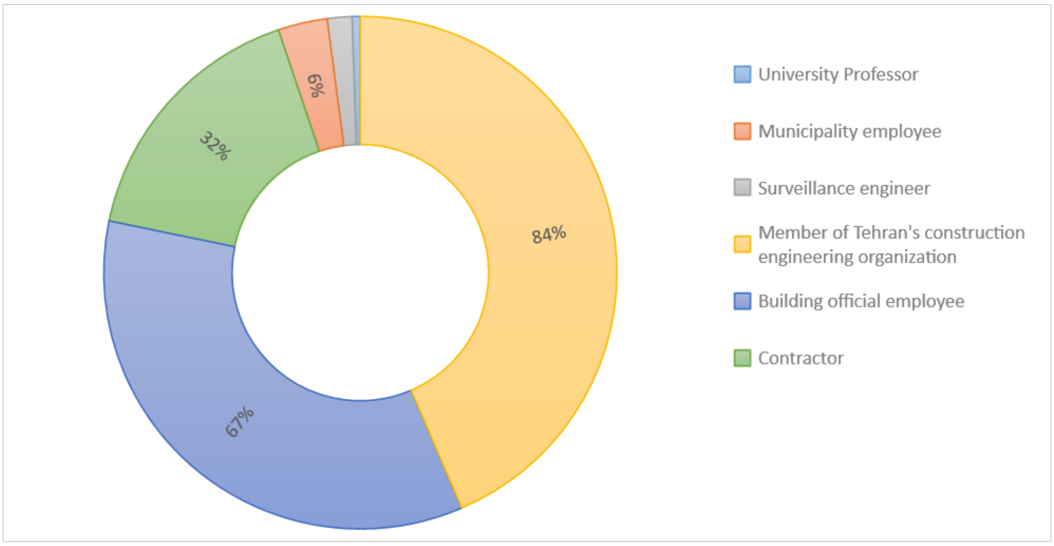


Figure 4-16: Highest educational qualification of the participants in the study

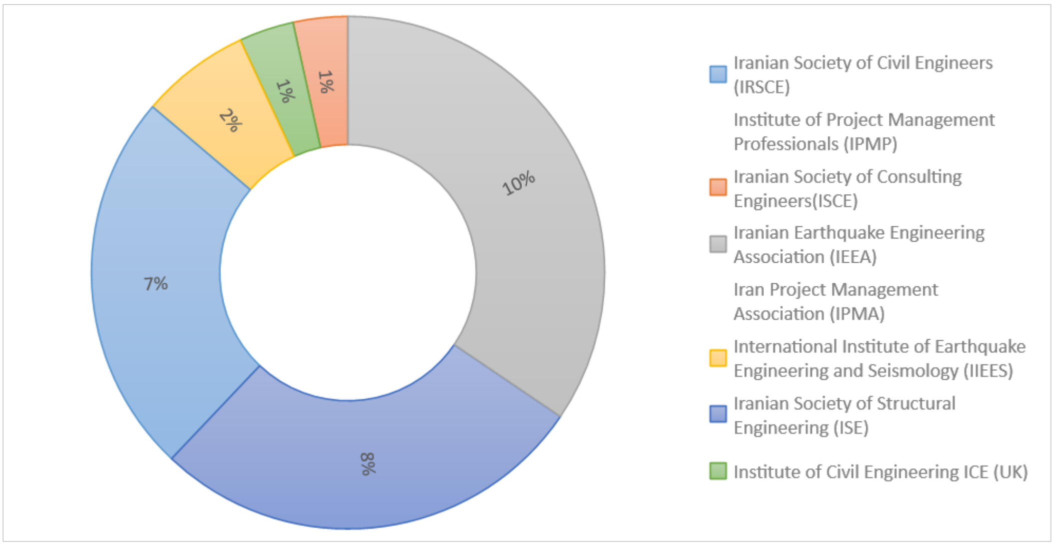


Figure 4-17: Participants professional memberships

Professional institutes and earthquake engineering associations are an effective source of information relevant to seismic codes which would benefit the awareness of the engineering community by ensuring that members are regularly informed and updated with pertinent knowledge and news. The author is a current member of the UK Institute of Civil Engineering (ICE) and frequently receives valuable information relevant to seismic engineering through online newsletters and articles. Furthermore, there are a large number of online educational tools made available to members that are useful in improving knowledge over a wide range of civil engineering disciplines including earthquake sciences.

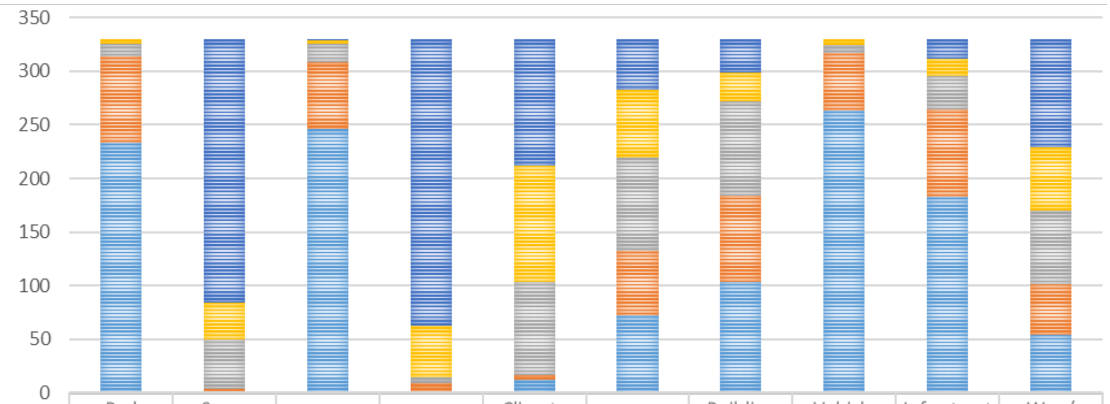
Construction engineers have an ethical responsibility to operate within a specific level of professional competence. The honesty and integrity of engineers are amongst the top priorities of ethical practice, to neglect these values could result in an environment susceptible to corruption (Lawlor, 2013). Construction professionals, when members of professional institutes or engineering societies, are usually aware of the latest ethical codes of practice and are encouraged by the institutes to adhere to the codes of practice, they may also be informed of the consequences of ethical neglect and subsequent impacts upon the quality of construction works. The results of the survey indicate that the respondents are not motivated to become members of professional communities. This, unfortunately, will result in the respondents not being regularly exposed to updated knowledge regarding earthquake engineering technology or ethical codes of practice, thereby compromising the seismic performance of buildings and the quality of construction supervision.

4.3.2. Part 2: Hazards in General

This section examines the respondents' thoughts regarding hazards in general. The participants were requested to identify the hazards which pose the highest threat to their communities. This subjective information is essential for the researcher to determine the significance of each hazard and evaluate the perceived level of risk presented by earthquakes in comparison to other hazards in the city of Tehran.

Earthquakes are widely acknowledged to be the most threatening hazards in Tehran and the country as a whole. The two most destructive earthquake events to have occurred in Iran over the last thirty years include the 1990 Manjil-Rudbar Earthquake accounting for approximately 60,000–105,000 injuries and 35,000–50,000 fatalities, and the 2003 Bam Earthquake accounting for approximately 30,000 injuries and 26,000 deaths. These seismic events are a strong basis upon which to spread awareness of earthquakes and their devastating impacts.

The data in Figure 4-18 indicates that vehicular accidents, earthquakes, and severe air pollution derived from the large volume of automobile emissions, carbon-based energy emissions, and industrial factories are the most frequent and destructive events which threaten the population of Tehran. Approximately 80% of respondents believe that they are at risk of being affected by vehicular accidents. Followed by 74% of respondents who consider earthquakes to be at imminent risk. Inclement weather was identified by 70% of respondents as a substantial threat to their communities. While a further 20% of respondents identified crime as a legitimate danger to their welfare. It is to be noted that less than 1% of the participants believe landslides to be a considerable threat to the community and less than 1% regard snowstorms to be of legitimate risk.



	Bad weather	Snow storm	Earthquake	Landslide	Climate change	Crime	Building fires	Vehicle accident	Infrastructures failure	War / Terrorism
5 Lowest likelihood	0	246	1	267	118	47	31	0	18	101
4	4	34	4	48	108	64	27	6	16	59
3	12	46	17	6	87	87	88	7	32	69
2	81	2	62	7	5	60	81	54	81	47
1 Highest likelihood	233	2	246	2	12	72	103	263	183	54

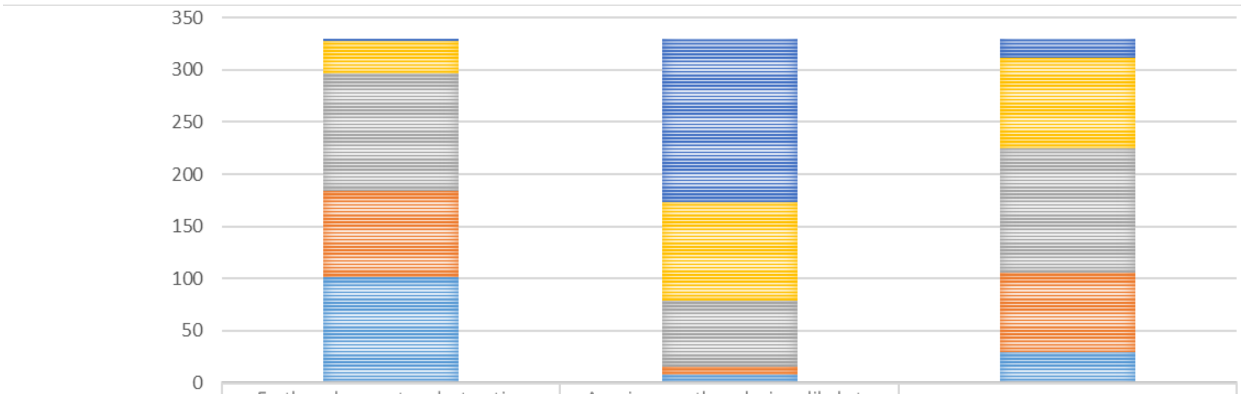
Figure 4-18: Likelihood of events to affect Tehran

Additionally, 31% of respondents believe poverty to be a hazard of risk within their community, while 15% of respondents identified flood as a hazard of concern, and 13% of respondents concurring that personal health poses a threat to the welfare of the community. The results obtained from the questionnaire indicate that 62% of the participants have been personally affected by these hazards whether directly or indirectly of which 46% have been affected by vehicular accidents. 23% of the respondents have been affected by earthquakes, while 23% have been affected by air pollution and a further 31% of respondents having been impacted by criminal activities such as theft or assault.

4.3.3. Part 3: Preparation for an Earthquake

This section examines the thoughts of respondents regarding earthquakes and their attitudes towards earthquake preparedness. The opinions of respondents concerning the probability of earthquake occurrence and the role of construction practitioners in the reduction of earthquake impacts shall also be explored. The data gathered in this section is an essential part of this research enabling the researcher to determine if construction practitioners in Tehran have been adequately informed regarding the probability of an earthquake event, the role of construction practitioners in the reduction of seismic impacts, and whether or not they are undertaking any beneficial action towards the reduction of seismic impacts within their field of construction and what problems do they encounter with.

Approximately 63% of the respondents are confident that they have sufficient knowledge to minimise the impacts of potential seismic hazards. The data illustrated in Figure 4-19 indicates that a 56% majority of participants share the opinion that earthquakes are destructive hazards, whereas 10% of participants believe that earthquakes are not necessarily associated with any harmful effects. Overall the respondents concur that an effective disaster management plan has the potential to reduce the negative impacts of an earthquake event. It is noted that only 5% of respondents state that they have not personally encountered an earthquake event in their lifetimes, while 95% of respondents claim to have had some experience of earthquakes in their lives. Of the 56% majority of respondents which they believe earthquakes to be a destructive hazard, approximately one-third of this majority believe that it is not difficult to prepare for an earthquake, while another third of this majority believe the process of earthquake preparedness to be a difficult task.



	Earthquakes are too destructive hazards	A serious earthquake is unlikely to occur during my lifetime	It's hard to prepare for earthquakes
5 Strongly Disagree	2	157	18
4	31	94	87
3	113	63	119
2	83	8	77
1 Strongly Agree	101	8	29

Figure 4-19 Earthquake hazard

A 99% majority of respondents agree that any information which they have received on the subject of hazards is limited to general information, with the remaining 1% of respondents stating that have received no information on the subject. Figure 4-20 illustrated that the sources utilized by respondents to obtain information on the subject of disaster preparedness consist of media sources such as internet, television, radio, and newspapers (96%); construction engineering societies (85%); and universities or schools (70%). Less than 10% of respondents stated that they had obtained disaster preparedness information from government-sponsored disaster management organizations.

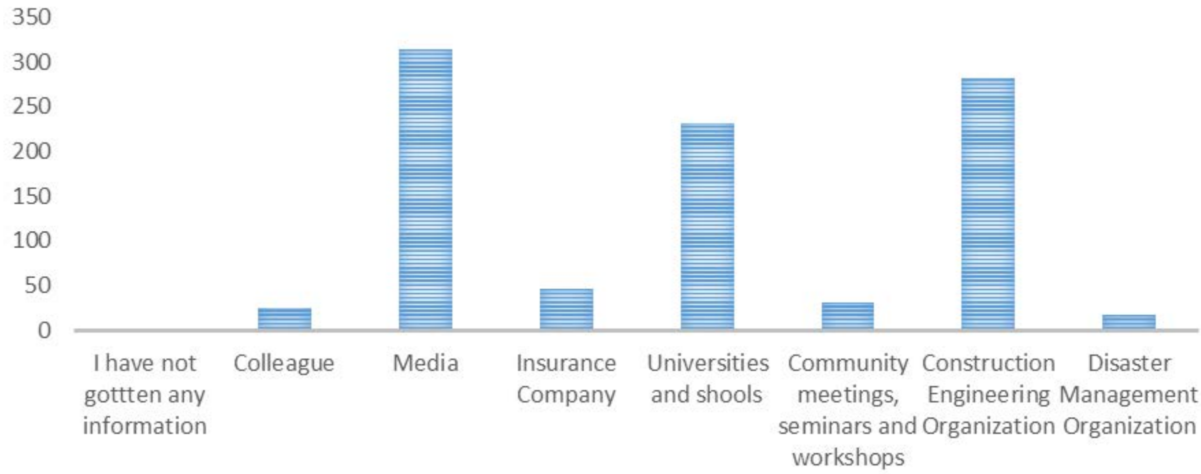
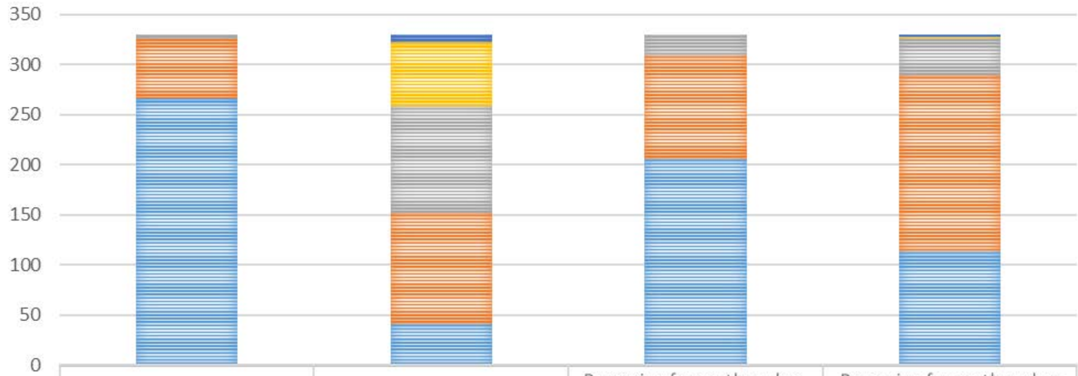


Figure 4-20: Earthquake information sources

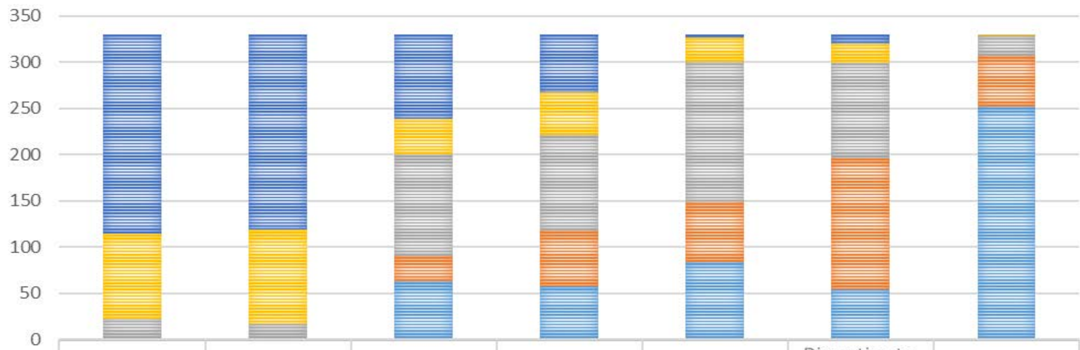
The survey results illustrated in Figure 4-21 indicates that a 98% majority of respondents believe that good construction practice can significantly reduce the impacts of earthquakes by minimising damages sustained by buildings during a seismic event. This 98% majority states that good construction practice not only reduces the damages sustained by buildings but also serves to increase the value of buildings (94% agree) and extend the lifespan of said buildings (87% agree).



	Preparing for earthquakes through good construction practice will significantly reduce damage to buildings	Preparing for earthquakes through good construction practice will enhance my everyday living conditions	Preparing for earthquakes through good construction practice will improve the value of buildings/properties	Preparing for earthquakes through construction practice will enhance the life of the building and ultimately is of cost-benefit
5 Strongly Disagree	0	8	0	2
4	0	64	0	1
3	5	106	21	38
2	59	111	103	176
1 Strongly Agree	266	41	206	113

Figure 4-21: Earthquake Preparedness

Figure 4-22 illustrates that 85% of respondents believe there is the possibility of a strong earthquake occurrence in Tehran. Approximately 40% of the respondents state that the majority of buildings in Tehran would not be capable of sustaining the seismic forces of a strong earthquake, while 36% agree that there is an absence of planned escape zones. The data also indicated that approximately half of the respondents agree that the most significant impact on the vulnerability of communities is derived from infrastructure damages and the disruption of services such as water supply, power supply, gas supply and communications systems. 93% of respondents also believe that earthquakes which occur during the night or during the winter months increase the vulnerability of the community and the overall impacts of the earthquake.



	There may be earthquakes, but they won't be that bad	The location of the earthquakes will be far away from our district and will have little impact on us	The buildings in our district are earthquake-proof buildings, and they are safe	Escape zones for earthquake emergencies are not planned in the buildings	Disruption of water, infrastructure damages, and power failure have most impact on us	Disruption to other services such as communication, gas, sewerage and fire have most impact on us	The potential impacts would depend on the exact nature of the event, including the time and season
5 Strongly Disagree	215	211	91	63	3	10	0
4	93	102	39	46	27	21	1
3	21	16	109	103	151	103	22
2	0	0	28	61	65	142	55
1 Strongly Agree	1	1	63	57	84	54	252

Figure 4-22: Earthquake impacts in built environment

The results illustrated on Figure 4-23 indicate that 73% of respondents rarely or never discuss the problems presented by earthquakes in the context of construction with other construction practitioners and that a further 86% of respondents rarely or never attend seminars on the subject. Additionally, professional cooperation aimed at improving construction practices in anticipation of future seismic events is seldom undertaken between construction practitioners.

	I talk about earthquake problems and issues regards to construction practice with the other construction practitioners	I attend seminars relevant to construction practice and its impact to reduce earthquake problems and issues	I have worked with other construction practitioners to find ways of improving construction practice for future earthquakes
Never	72	187	119
Rarely	169	96	192
A few times a year	64	39	13
Once a month	19	3	1
A few times a month	1	0	0
Once a week or more	5	5	5

Figure 4-23: Built environment professionals' collaboration in programs related to earthquake risk reduction

4.3.4. Part 4: The Impacts of an Earthquake

This section examines the perspectives of the respondents in regards to the built environment and the role of construction practitioners in the reduction of earthquake impacts. The researcher investigates the inherent technical complexities and ethical constraints in construction practice. Additionally, the researcher will evaluate the quality of construction materials and workmanship across the various districts of Tehran. Several important technical issues such as the presence, or lack thereof, of building construction regulations, construction safety regulations and routines, and enforcement surveillance are surveyed in this section. The survey participants are also presented with questions relating to unethical behaviours which may be encountered during construction practices and their effects on the quality of construction work in Tehran. Furthermore, factors such as building height and the age of buildings which may affect the integrity and stability of building throughout Tehran's various districts shall also be investigated.

Figure 4-24 illustrates the average age of buildings across the 22 districts of Tehran as estimated by the respondents. The respondents determine that the average age of buildings in District 22 is 5-10 years, while the average age of buildings in Districts 1, 2, 3, 4, 5 & 19 is 10-20 years, and the average age of buildings in Districts 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20 & 21 is greater than 20 years.

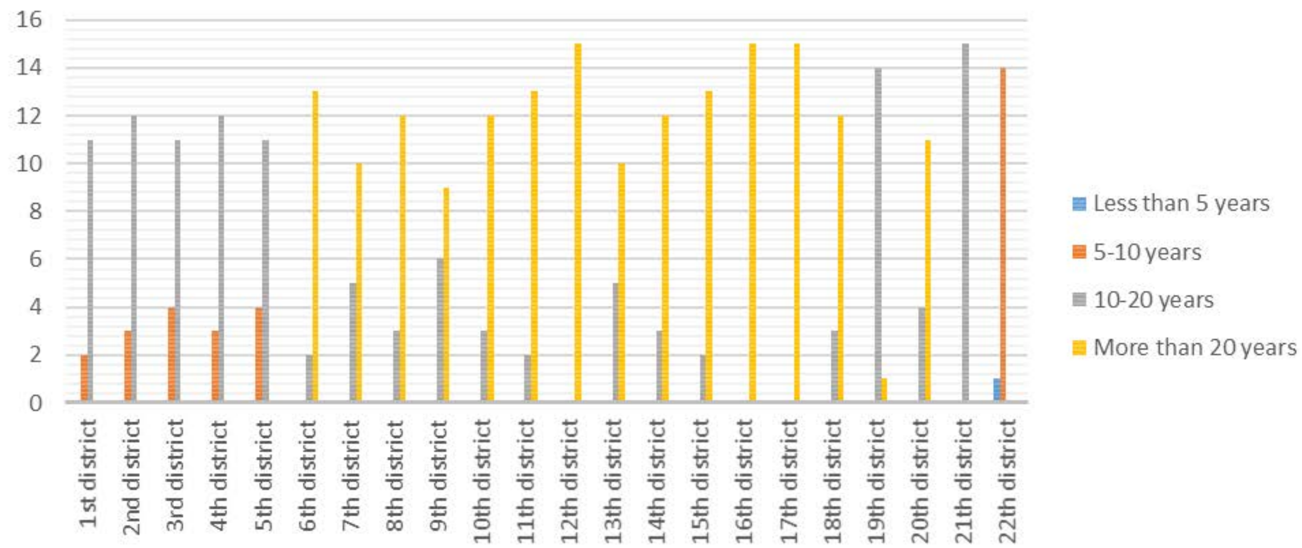


Figure 4-24: Average buildings age in Tehran's districts

The opinions of respondents in regards to the quality of construction materials and the quality of workmanship across Tehran's 22 districts indicate that the construction in Districts 1, 2, 3, 4, 5 & 6 benefit from good quality construction materials while the remaining districts suffer from moderate to poor construction materials, and that the construction in Districts 1, 2, 3, 4 & 6 benefit from good quality workmanship while the construction in remaining districts suffer from moderate to poor quality workmanship.

Figure 4-25 illustrates the typical height of buildings across Tehran's 22 districts as assessed by the respondents. According to the respondents, the average height of buildings in District 1 is higher than 8 storeys, while the average height of buildings in Districts 2, 3, 4, 5, 6, 7, 8 & 22 is 4-7 storeys, and the average height of buildings in Districts 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 & 21 is 1-3 storeys.

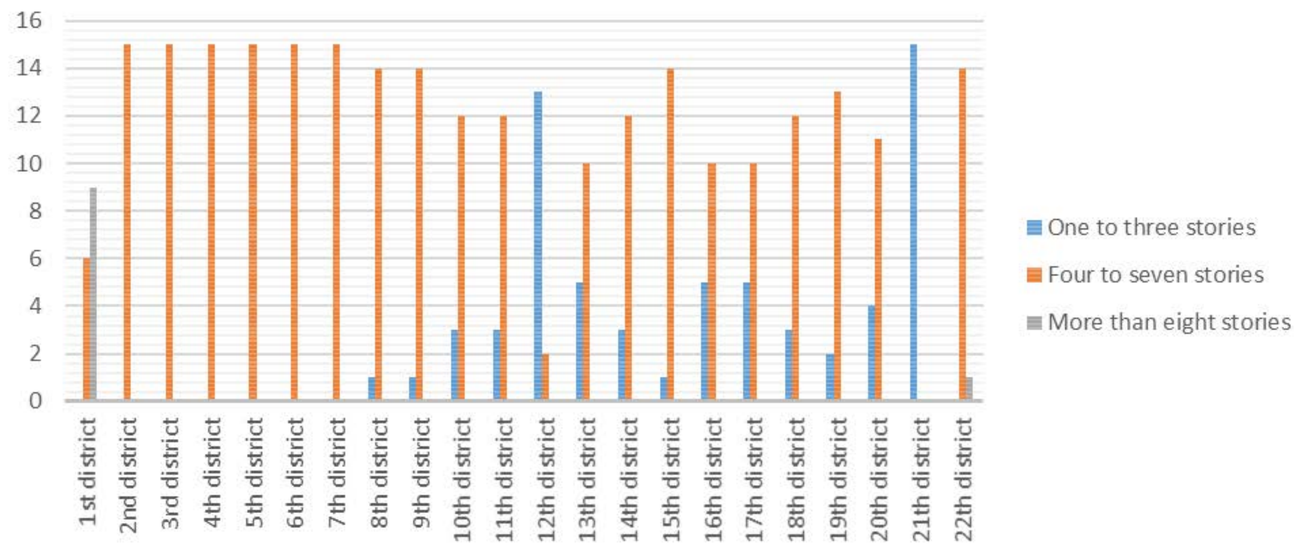
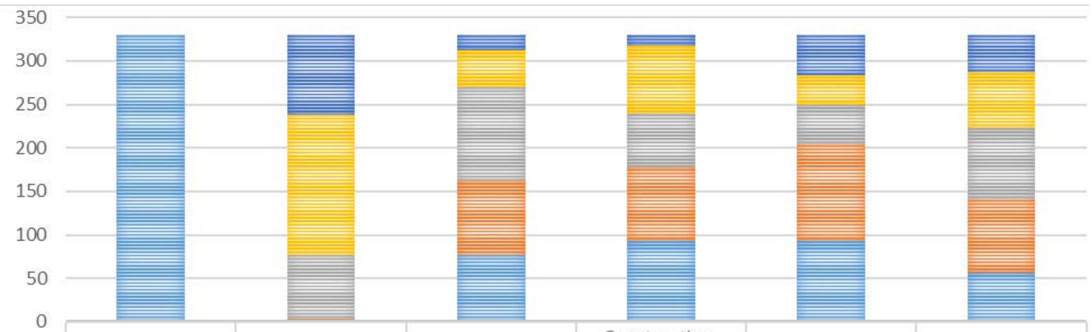


Figure 4-25: Typical buildings height in Tehran's districts

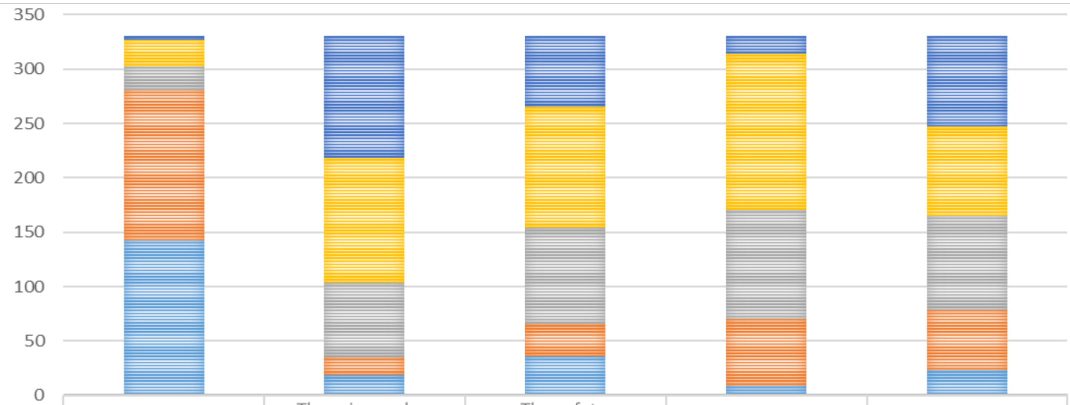
The results illustrated in Figure 4-26 indicate that all respondents believe that there are rules and regulations with respect to seismic hazards and safety. However, 77% of respondents believe that there is not enough training on the subject, 23% of respondents believe that the authorities do not conduct sufficient assessments regarding the performance of construction practitioners, 32% of respondents claim that the unfair and unjust treatment of construction practitioners has a detrimental impact upon construction, and 18% of respondents believe there to be insufficient time for construction planning, all of which are significant hindrances upon the seismic resistance of built environments. Furthermore, 24% of respondents believe that construction practitioners do not receive adequate financial restitution to perform their jobs efficiently.



	There are rules and regulation to follow in relation to seismic hazards	Construction practitioners get enough training to perform their job adequately.	The plan time schedule for each building construction is reasonable.	Construction practitioner's performance will be measured by the authorities or the construction industry	Construction practitioners earn enough money to perform their job.	Construction practitioners do their jobs fairly and justly.
5 Strongly disagree	0	92	17	13	46	43
4	0	161	43	77	35	64
3	0	74	108	63	45	82
2	0	3	85	84	111	84
1 Strongly agree	330	0	77	93	93	57

Figure 4-26: Construction practitioner constraint in built environment preparedness

Figure 4-27 illustrates that although 85% of respondents believe that there are current regulations for safety systems, 68% of respondents state that there is an absence of well-enforced surveillance over building safety compliance. 48% of respondents also report that buildings in Tehran are not equipped with fire-fighting systems, while 50% of respondents state that the buildings are not equipped with building management systems, and 53% of respondents believe safety infrastructures to be poorly designed.



	There are strict regulations for building's safety system	There is regular, efficient and well-enforced surveillance in observing buildings' safety laws	The safety infrastructure of the buildings are well designed and executed	Buildings are equipped with firefighting system and emergency plan	Buildings are equipped with BMS to deal with building damages
5 Strongly disagree	3	112	65	16	83
4	25	114	111	144	82
3	21	69	88	100	87
2	139	16	30	61	55
1 Strongly agree	142	19	36	9	23

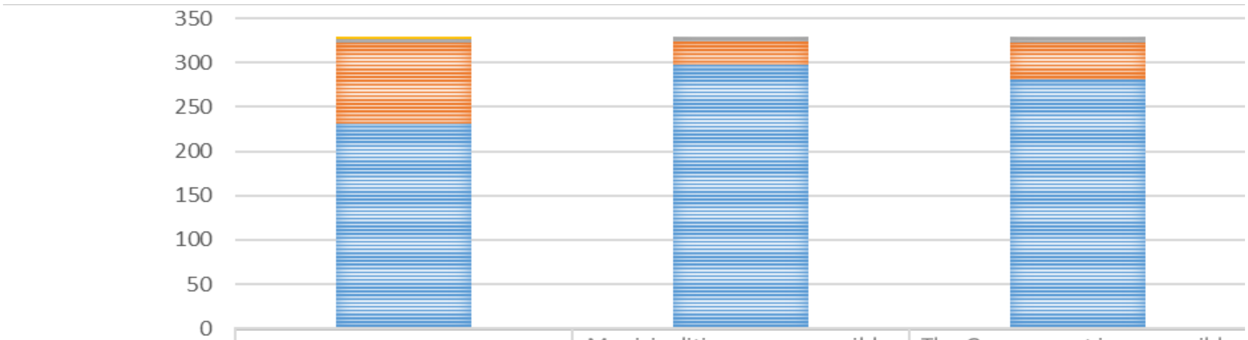
Figure 4-27: Utilizing buildings' security systems for preparing built environment to deal with earthquake

The respondents identified certain unethical practices present within Tehran's construction industry which they feel to be the most significant unethical factors affecting the quality of construction; 81% of respondents claim that competitors exaggerate their qualifications and professional capacity in order to secure work, 78% of respondents state that late payment and short payment is a problem, 68% of respondents highlight a lack of safety ethics by subcontractors, 47% of respondents identify non-compliance with regulations to be a serious unethical practice, 46% of respondents identify the unfair treatment of contractors during financial/tender negotiations, 45% of respondents believe poor documentation to be of concern, and 39% of respondents identify bid cutting as an unethical practice present within Tehran's construction culture. All of the above factors are detrimental to overall building construction quality and may lead to an increased risk of seismic impacts and damages.

4.3.5. Part 5: Responsibility for Earthquake preparation

This section examines the opinions of respondents regarding the responsibility of authorities (i.e., Government, Municipalities, Society of Engineering, Disaster Management Organisations and Construction Communities) and their roles in the reduction of earthquake impacts. Survey participants were presented with questions concerning the support which may be needed to monitor seismic activity in order to collect data which can contribute to the construction of earthquake resistant buildings and the retrofit of existing structures for the purposes of increased seismic resistance. The respondents' views upon the subject of building regulation enforcement shall also be explored.

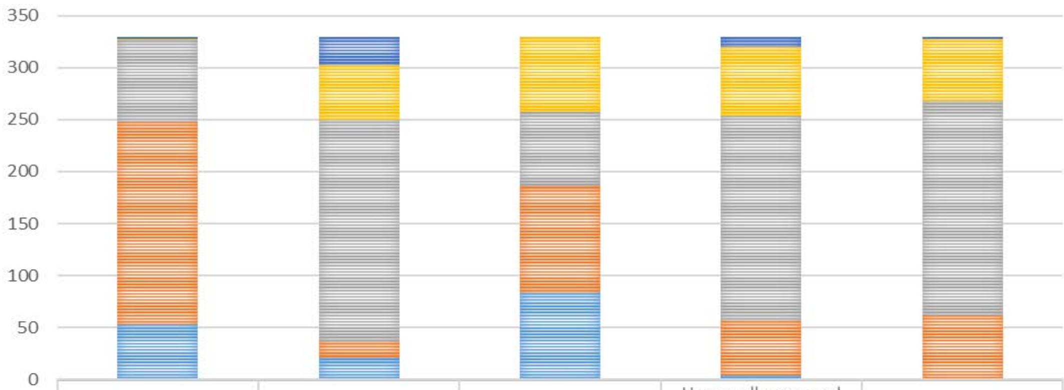
As illustrated in Figure 4-28, 87% of respondents concur that government must be ultimately responsible for the regulation of construction practice in anticipation of any major seismic events within Tehran. Furthermore, 75% of respondents agree that local municipalities have a high level of responsibility regarding the regulation of building construction. 99% of respondents state that they never neglect their responsibilities in regard to seismic safety and impact reduction, while only 1% of respondents state that they feel little or no responsibility towards ensuring compliance with seismic building codes. Overall the results indicate that the respondents believe the entire engineering community share responsibility over the reduction of earthquake impacts upon the built environment and that among these groups it is the local municipalities which hold the most influence over earthquake preparation within built environments.



	I feel responsible for the regulation in construction preparations for a major earthquake	Municipalities are responsible for the regulation of engineering practice in preparation for major earthquake	The Government is responsible for the regulation of engineering practice in preparation for major earthquake
5 Strongly disagree	0	0	0
4	3	0	0
3	4	6	7
2	92	27	42
1 Strongly agree	231	297	281

Figure 4-28: Responsibility for the regulation of engineering practice in preparation for a major earthquake

The results illustrated in Figure 4-29 indicate the respondents' opinions regarding the preparedness of various engineering groups in coping with the impacts of an earthquake event. Only 25% of respondents believe that the government is prepared for an earthquake to some degree, while 44% of respondents believe that municipalities are empowered to monitor construction practices to some degree. The participants indicate that the poor operation of municipalities and their failure to adequately oversee construction activities directly contributes to the decreased seismic resistance of buildings. According to the respondents, the monitoring of construction by the municipal councils could help to improve the quality of construction and prove an effective means of reducing seismic impacts. The confidence of respondents is higher in regards to the preparedness of the private sector. 88% of respondents believe that contractors are prepared to some degree for the impacts of an earthquake, while 82% of respondents believe that industry professionals are prepared for the impacts of an earthquake to some degree, and 81% of respondents believe that engineering consultants are prepared for the impacts of an earthquake to some degree.



	How well prepared is the Government for a major earthquake?	How well prepared are contractors for a major earthquake?	To what extent is the district municipal council empowered to monitor construction practice?	How well prepared are Tehran construction engineering professionals for a major earthquake?	To what extent are consultants empowered to monitor construction practice?
5 Very prepared	2	27	0	10	2
4	1	53	72	66	60
3	79	213	72	197	206
2	195	16	102	53	62
1 Not at all prepared	53	21	84	4	0

Figure 4-29: **Level of preparedness of different community members and groups to deal with a major earthquake**

A 94% majority of respondents share the opinion that existing rules and regulations are not sufficient to ensure the adequate monitoring and control of construction in unstable regions and fault zones. Approximately 63% of respondents report that although there are comprehensive regulations in place, these regulation are not enforced by engineers. A further 30% of respondents believe that the existing regulations are not complete.

In regards to the existence of essential regulatory support towards the implementation of seismic retrofit, 77% of respondents believe that there is relevant regulatory support in place while 22% of respondents stated that they were not sure whether or not these supporting regulations exist. Furthermore, a 76% majority of respondents claim that the main source of financial funding for seismic retrofit projects is governmental loans, while 22% percent of respondents believe the main source of funding to be from building owners, and only 1% of respondents believe that financial institutions such as banks are the primary source of retrofit funding.

Figure 4-30 illustrates the respondents’ views regarding the renewal rate of buildings across Tehran’s 22 municipal districts. Respondents report that renewal rate of buildings differ between the various districts as follows: District 22 has a renewal rate of between 81-100%, Districts 1, 2, 3, 4, 5, 6 & 21 have renewal rates of between 61-80%, Districts 7, 8, 9, & 10 have renewal rates of between 41-60%, and Districts 11, 12, 13, 14, 15, 16, 17, 18, 19 & 20 have renewal rated of less than or equal to 40%.

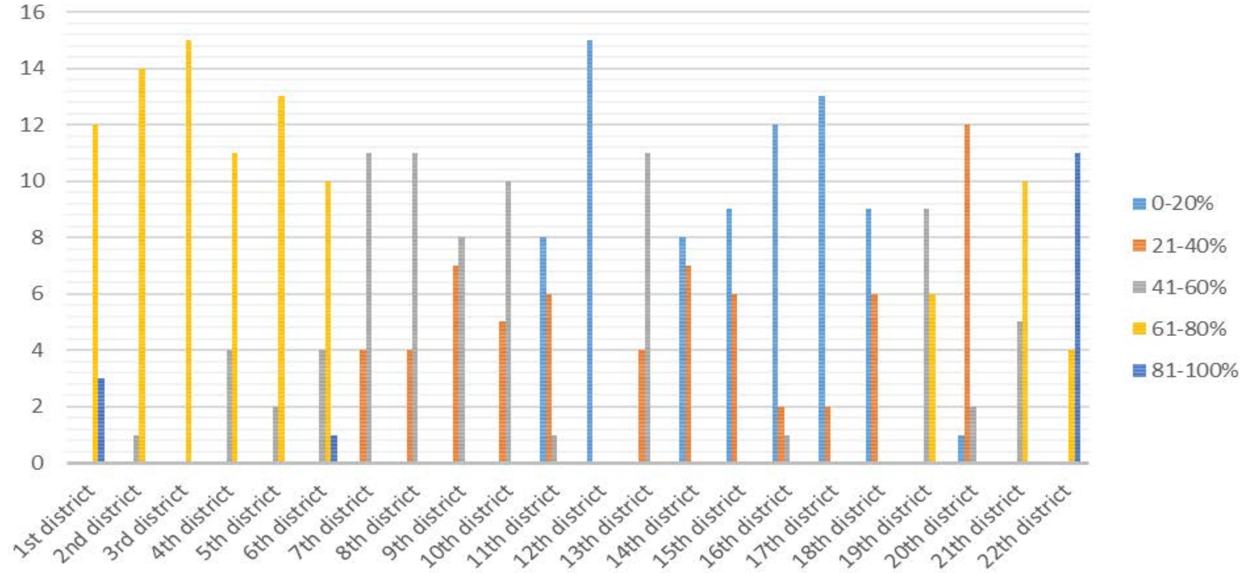


Figure 4-30: Renewal rate of the buildings in Tehran's districts

The results illustrated in Figure 4-31 indicate the respondents' opinions regarding the existence of sufficient space for the mass care and sheltering of victims and displaced populations after the occurrence of an earthquake. The findings indicate that central districts of Tehran such as Districts 9, 10, 11 & 12 suffer from a lack of available space for emergency shelter. Furthermore, 91% of respondents agree that a standardized system for the examination of building safety does not exist.

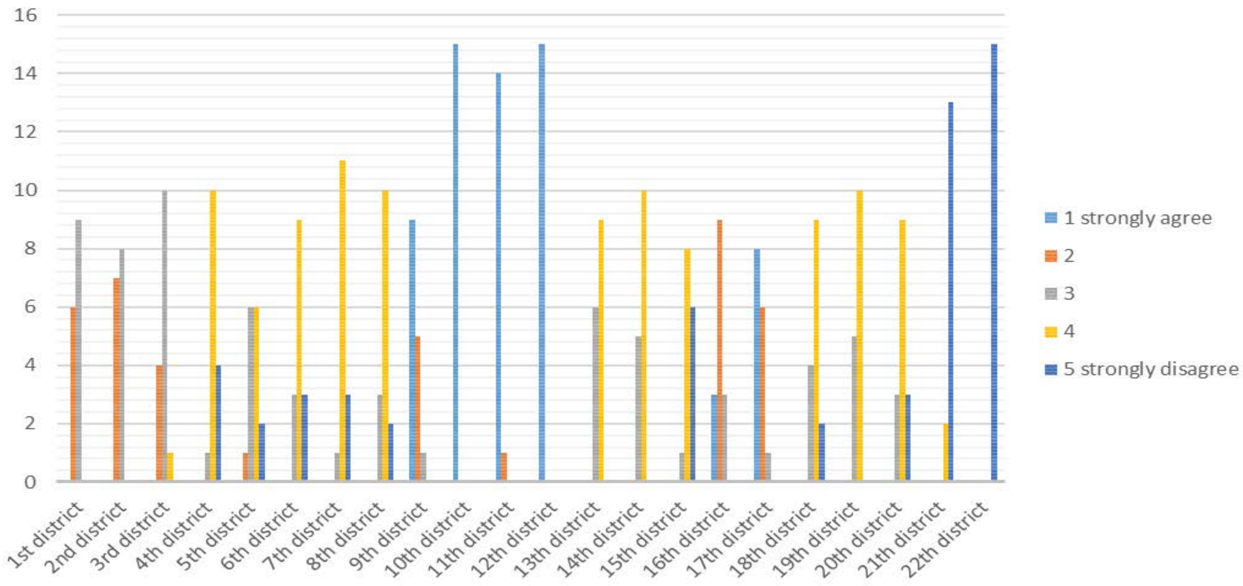
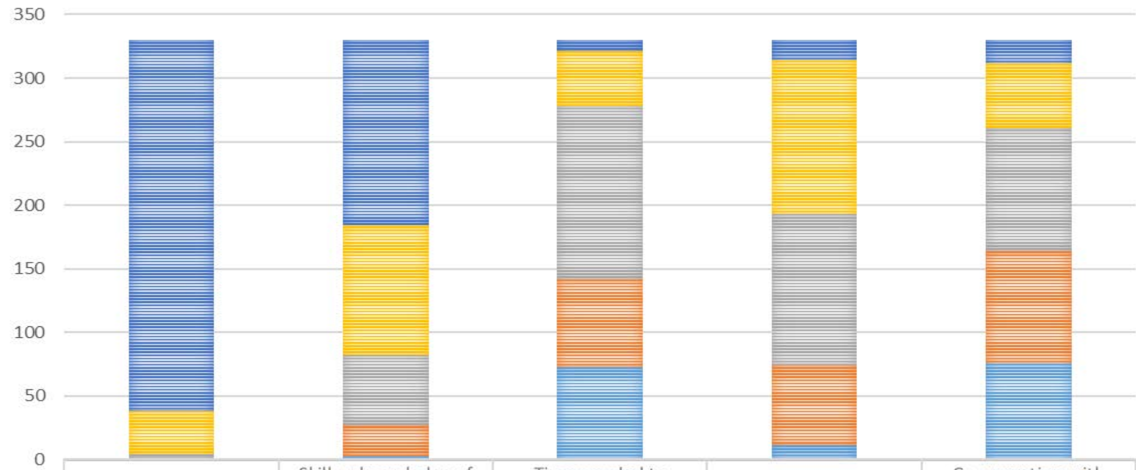


Figure 4-31: Existence of sufficient free space in districts for sheltering of victims

Figure 4-32 indicates that 99% of respondents believe that financial issues are the primary constraint on the development of seismic-resistant built environments. 75% of respondents also believe that the knowledge of staff is a further constraint in this regard, 41% of respondents identify the unavailability of adequate construction materials as a challenge in the efficient construction of seismic resistant buildings, 21% of respondents identify inter-professional cooperation as an obstacle in this process, and 16% of respondents believe that a lack of sufficient planning time for such projects to be another primary barrier for developing seismic-resistant built environments.



	Cost	Skill or knowledge of staff	Time needed to prepare	Materials	Co-operation with others
5 Great deal	292	146	9	16	18
4	34	102	43	121	51
3	4	55	136	119	97
2	0	24	69	63	88
1 Not at all	0	3	73	11	76

Figure 4-32: The main constraint in preparing Tehran's built environment to deal with an earthquake

4.4. Qualitative Data Analysis: Semi-structure Interviews

Qualitative data obtained through semi-structured interviews shall be analysed in this section. As explained in chapter three, twenty construction engineers currently active in Tehran were selected to participate in the interviews. The primary objective of the interviews is to obtain perspectives which further the findings of the quantitative questionnaire in greater detail and to explore the strengths and weaknesses of construction professionals in their preparations to cope with a potential major earthquake in the city of Tehran. In this section, any research questions requiring deeper explanations not obtained through the quantitative questionnaire are proposed to the respondents for further discussion and any key findings which assist the researcher to explicate the results of the survey shall be presented.

4.4.1. Earthquake Disaster Awareness and Preparedness by Construction Practitioners:

The primary research questions to be addressed pertaining to earthquake disaster awareness and preparedness of construction practitioners are as follows;

Question (A-a): Are construction practitioners aware of the significance which earthquake vulnerability plays upon social harm in the city of Tehran and to what extent are construction practitioners prepared to deal with an earthquake hazard?

The first step of earthquake disaster management is to inform community members of the probability of an earthquake. The relevant engineers whom directly and frequently influence the coping capacity of an entire community must be fully aware of the probability of an earthquake event. In the context of earthquake risk reduction, it is the role of built environment engineers to meet this objective. The high probability of a devastating earthquake occurring in the near future is widely acknowledged by the communities of Tehran. All interviewees support this belief and state that the government keeps community members informed of the risks of an earthquake through public announcements and media platforms. However, one respondent, Interviewee No. 7 argues that public announcements issued by the government address the subject in a general nature intended for the civilian population without any information being provided on professional issues.

Interviewee No. 7 believes that by organizing courses, workshops, and seminars which focus upon important professional issues, awareness can be raised among the engineering community. Interviewee No. 10 supports this opinion and states that:

"*In many occasions, engineers do not support and participate in courses, workshops, and seminars*."

In many cases, engineers are not interested in participating in seminars or workshops since the issues being discussed do not focus on earthquake engineering. Based on the experiences of Interviewee No. 10, only a limited number of high ranking construction engineers participate in professional seminars and workshops. Interviewee No. 10 continues by explaining that:

"*There are two main reasons behind this. Firstly, a lack of appropriate information from the organizer of the seminar leads to the absence of some engineers at these meetings. Secondly, construction engineers, as a busy society, must be sure that they will be participating in a seminar or workshop that addresses professional issues.*"

Interviewee No. 2 believes that although earthquake risk reduction is a concern of engineers, it will not be their primary concern as long as landlords are focused upon other issues and not upon the construction of earthquake resistant buildings. Interviewee No. 2 believes that if earthquake resiliency became a major concern of the building's owner community at large, construction practitioners would be inclined to devote greater attention towards increasing their knowledge respective to the design and construction of earthquake resistant buildings. Interviewee No. 2 continued by explaining that:

"*Engineer communities and any persons working in the construction industry, as economic activists, are seeking their own financial benefits and it is normal to follow the major concerns of the client.*"

Interviewee No. 2 believes that it is not only the responsibility of engineering communities to work towards the reduction of earthquake risk but also the responsibility of all other relevant stakeholders regardless of any potential financial implications. Interviewee No. 2 continues by explaining that although construction practitioners, due to the nature of their profession, may be directly responsible for the reduction of earthquake impacts, the financial decisions made by proprietors and end-users, and their cost versus profit targets, have the most influence over the size and scale of earthquake impacts. Proprietors could, for instance, implement specific criteria prior to investing in a property such as checking whether or not the property has a formal completion certificate, verifying the structural stability of the property against the relevant seismic codes, or only purchasing a property with valid insurance against natural disasters such as earthquakes, fire, and flood.

4.4.2. The Role of Construction Practitioners in Earthquake Risk Reduction:

The primary research questions to be addressed regarding the role of construction practitioners in earthquake risk reduction are as follows;

Question (B-a): To what extent to do engineers and supervisors have knowledge regarding seismic design and practice codes?

Question (B-b): Do construction practitioners regularly update their knowledge of standards and regulations of construction practice in relation to seismic codes and ductile detail requirements?

In order to evaluate the role of building practitioners in earthquake risk reduction, we must first identify the technical skill of construction practitioners in Tehran. Understanding the engineers' level of technical knowledge can help the researcher to determine whether or not the construction practitioners have the technical ability to effect earthquake risk reduction. All interviewees shared the belief that the majority of construction engineers operating in Tehran are not proficient within their fields.

Interviewee No. 8 explained that almost all of the people inclined to enter into the construction industry are those with the financial ability to do so. Therefore, the construction industry is saturated with participants who have financial security but lack any real knowledge of construction development. Interviewees No. 1 and No. 2 continued by explaining the underlying reasons for this tendency. Interviewee No. 1 highlighted that construction is viewed as the primary industry in Iran and that the insecurity of other industries has led to an increase in the number of businesspersons who wish to participate in the construction industry. Interviewee No. 2 added that the assured financial returns of construction development had generated massive demand for participating in the construction sector. Interviewee No. 3 supported this opinion and stated that due to the substantial financial returns earned by developers, there is a continuously increasing rate of investment in the construction industry thereby further increasing the volume of participants within the industry. Interviewee No. 3 continued by proposing the question:

"What if there is not a sufficient number of specialists in each field, while the volume of non-experts within the industry is increasing?"

Interviewee No. 6 viewed this subject from an alternative perspective and explained that the construction industry, by its own nature, is an economic activity seeking financial gain and, therefore, in many cases employers are inclined to hire employees which demand a lower salary whether they are specialists or not. Interviewee No. 20 highlighted that many construction practitioners with university degrees are not capable of implementing earthquake risk reduction strategies and suggested that inadequate practical training in universities is the main reason for this problem. Interviewee No. 14 imparted a different aspect to the discussion by explaining that collaboration between universities and the construction industry is essential for developing construction practitioners' critical skills and stated that, unfortunately, the relationship between universities and the construction industry in Iran lacks and at times fragile.

Interviewee No. 13 highlighted an essential topic of discussion and explained that approximately half of the buildings in Tehran were constructed over thirty years and therefore we must not only consider the practices of current construction practitioners but also the practices of construction practitioners over the last several decades. Interviewee No. 13 continued by explaining that:

"If you are asking whether the former engineers had necessary knowledge for earthquake preparation? Definitely Not. Thirty years ago, most of the people who worked in the construction industry were non-specialists. Thirty years ago, there was no strict engineering organizations or comprehensive regulations for earthquake preparation of the built environment."

Question (A-d): Are construction practitioners aware of how the quality of construction materials can influence the seismic vulnerability of a building and what problems may prevent the use of high-quality construction materials?

All of the interviewees shared the belief that the quality of materials used in construction is a crucial factor in the seismic resistance of a structure. Interviewee No. 12 explained that the majority of buildings in Tehran have been constructed with moderate quality materials and that buildings in some southern districts of Tehran are constituted of poor quality construction materials. Interviewee No. 12 continued that there only a limited number of buildings, primarily in Districts 1, 2 & 3, which benefit from the utilization of high-quality construction materials. Interviewee No. 9 explained that in some cases high-quality construction materials and systems such as prestigious building management system brands are not available in Iran due to international trade sanctions. Interviewee No. 11 supported this idea and added that even if such high-quality materials and systems were made available in Iran, the purchase cost would be too high due to Iran's currency depreciation.

All respondents agreed that financial constraints are the primary obstacles preventing the utilization of high-quality construction materials in Tehran. Interviewee No. 20 highlighted that weaknesses in other industries would affect the construction industry in the long term and explained that weaknesses in other industries in the region would ultimately lead to an inability to produce high-quality construction materials and systems locally. Therefore, any high-quality construction materials would be required to be imported from abroad, and local purchasers would be obliged to pay inflated prices on the imported materials.

4.4.3. The Role of Laws and regulations in Earthquake Risk Reduction:

The primary research questions to be addressed regarding the role of laws and regulations in earthquake risk reduction are as follows;

Question (C-b): Are there any laws and regulations in Tehran's construction industry pertaining to seismic safety or do engineers follow international standards?

In regards to the existence of earthquake-related construction regulations in Tehran, all of the interviewees shared the belief that there are appropriate regulations in place. However, Interviewee No. 19 highlighted that some of these regulations are obsolete which require updating and cites an absence of properly implemented geotechnical testing in support of this statement. Interviewee No. 19 continues by explaining that:

"*Geotechnical testing and soil investigation is a critical step in providing a stable subgrade to construct upon, but unfortunately it is done superficially and of poor quality in Tehran*."

Question (C-c): Are these laws and regulations sufficient to reduce the impacts of an earthquake and have these laws and regulations been frequently updated?

Interviewee No. 2 explains that although Tehran does have earthquake-related construction regulations in place, there are significant distinctions between the regulations of Tehran and those of international standards. Interviewee No. 2 believes that even if construction practitioners comply with Tehran's existing seismic regulations, many buildings will collapse in the event of a strong earthquake. Interviewee No. 2 suggests a comparison between the seismic regulations of the Dubai, United Arab Emirates, against those of Tehran and concludes that Tehran's seismic regulations are significantly below the standards of Dubai's counterpart regulations. Interviewee No. 19 continues by highlighting that:

"*Recently, specialists have understood that the Iranian Seismic Code (2800) is not sufficient for an earthquake of a magnitude greater than 6.0 Richter, so structural engineers believe that in order to calculate the seismic resistance of buildings against earthquakes the implementation of code UBC 97 is more efficient than the Iranian Seismic Code*."

Interviewees 5, 9, 10, 11, 12 & 15 agreed that although there are seismic regulations in place, there is an absence of well-enforced surveillance to ensure compliance during construction. Interviewee No. 4, a municipality employee, explained that all data relevant to seismic resistance is documented by the municipality during the design stage of a construction project and that during the design stage there is stringent monitoring. Interviewee No. 4 stated that the majority of regulatory non-compliance could be observed during the construction supervision phase, and explained that it is easier for developers to circumvent regulations during the execution of construction. Interviewee No. 7 supported this opinion and suggested that undisciplined inspections by oversight engineers are a significant contributor to regulatory non-compliance.

4.4.4. The Role of Ethical Practice by Practitioners in Earthquake Risk Reduction:

The primary research questions to be addressed pertaining to the role of ethical practice in earthquake risk reduction are as follows;

Question (E-a): To what extent do construction practitioners in Tehran feel that ethical practice is an essential component of their profession and are these professionals involved in any form of corruption or bribery which may compromise the quality of construction works?

Interviewee No. 2 highlighted construction practitioners, as any working professionals, seek financial gain and conduct business with a profit-first mentality. Therefore, in order to attain profits, the use of high-quality construction materials may not be possible at all stages of construction, and some compromises must be made. Interviewee No. 2 continued by explaining that:

“Unfortunately, some employers are not satisfied with only reasonable profits in exchange for the utilization of better quality of materials in building construction. Therefore, this raises an ethical issue about the quality of construction materials potentially being used by construction practitioners.”

Virtually all of the interviewees unanimously agreed that bribery has negatively and substantially impacted Tehran’s construction industry. Interviewee No. 2 explained that despite the significant responsibilities borne by supervisory engineers, they often receive meagre salaries and little return for their efforts. This unfortunate reality commonly results in susceptibility towards unethical practices such as bribery. Interviewee No. 2 continued by disclosing that:

“I know that some developers carry a lot of gold coins on occasions and festivals such as Eid, and hand them out to municipal engineers one-by-one as a gift. They do this to coerce the municipal engineers into approving some non-standard works in the future, possibly without conducting the necessary inspections.”

4.4.5. The Role of Government and Authorities in Earthquake Risk Reduction:

The primary research questions to be addressed regarding the role of government and authorities in earthquake risk reduction are as follows;

Question (D-a): To what degree would the local government and Tehran municipalities bear responsibility towards the implementation of the required seismic regulations?

Question (D-b): Is the responsibility of the local government and Tehran municipalities sufficient to manage disaster events and if not, why do they not wish to provide a suitable response?

In regards to the role of government and authorities in earthquake risk reduction, the researcher asked the interviewees to express their opinions on the subject which was met by the interviewees with notable interest. Interviewee No. 12 stated that the government is responsible for supporting the relevant organizations to reduce earthquake impacts and accommodate their requirements. Interviewee No. 12 highlighted that the government had established the Iranian Construction Engineering Organization (IRCEO) to provide comprehensive, integrated regulations and training for construction professionals to improve the quality of construction within the country. Interviewee No. 12 added that:

"*The government have also recently developed the National Disaster Management Organization (NDMO) in an effort to increase the nation's capability in dealing with disasters*."

Interviewee No. 13 explained that the government is responsible for providing adequate infrastructures and public services in each district such as hospitals, fire stations, water supply stations, etc. Interviewee No. 13 continued by highlighting that, unfortunately, the infrastructures are not uniformly distributed among Tehran's districts with a substantial distinction between the northern and southern districts. Hence, the poor quality of infrastructures in the densely populated southern districts leads to increased vulnerability thereby resulting in higher losses in the event of natural catastrophes such as earthquakes. Interviewee No. 15 explained that a lack of coordination between the Iranian Construction Engineering Organization (IRCEO), as the surveillance branch, and the local municipality, as the executive branch, further contributes to regulatory non-compliance during construction projects.

Interviewee No. 9 adds that local leaders and persons of influence within the community could take action towards the reduction of disaster impacts. Interviewee No. 9 provided an example of this scenario and imparted that:

“Two years ago, an earthquake with a magnitude of about 5.0 Richter struck a small village in a remote area in which most of the buildings were constructed with non-resistant materials such as wood, stone, and thatch. Nearly all of the buildings including homes and barns were totally destroyed, and the villagers lost all of their belongings. A respected village elder, with connections within the government, communicated with an insurance agency and persuaded the agency to compensate the costs of the damages which enabled the villagers to reconstruct the buildings which had been destroyed.”

This example clearly demonstrates that strong leadership and government foresight could provide significant benefits to community members and their livelihoods. Interviewee No. 1 stated that governments should be capable of executing an emergency action plan in disaster scenarios and continued by explaining that having a predetermined plan for such circumstances is vital for reducing the impacts of a disaster event. Interviewee No. 11 reported that in previous disasters such as the Bam Earthquake in 2003, the recovery and reconstruction efforts of the Iranian government were poorly coordinated and repeatedly delayed. Interviewee No. 12 highlighted that a significant problem in Iran’s emergency and evacuation plan is that the related government branches and organizations often attempt to deny responsibility for any requirements or shortcomings. Interviewee No. 12 added that:

“The irresponsibility of government organizations, even is cases less complex than an earthquake disaster, is frequently observed in Iran…….when things do not go right the Iranian authorities often blame others, offering a scapegoat rather than accepting responsibility for any failures .”

Another important responsibility of the government in earthquake risk reduction is to prevent any construction in high-risk areas such as fault zones. All of the interviewees agree that there are no enforced government regulations which prevent the construction of buildings in active fault zones. Interviewee No. 8 provided an example of this problem by stating that the majority of high-rise buildings in Tehran have been constructed in District 1 which is located in an active fault zone. Interviewee No. 11 expressed that there are a large number of low-quality construction projects in Tehran’s countryside operating without building permits which further increases the potential negative impacts of an earthquake.

Interviewee No. 7 stated that existing buildings in the antiquated areas of Tehran, although not located within fault zones, could succumb to even greater damages than that of newer construction located within fault zones. Interviewee No. 7 believes that the antiquated areas of central and southern Tehran are the most vulnerable regions of the city and that even a minor earthquake in these locations could result in absolute devastation due to the weakness of the old buildings. Interviewee No. 1, focusing on the urban planning problems in the old parts of the city, stated that limited access in the southern districts, i.e., very narrow and non-standard roadways, would be a major problem in an earthquake disaster scenario. Interviewee No. 1 explained that:

"Dense populations in the central and southern districts of Tehran along with a lack of emergency shelters could result in the widespread loss of human life."

Interviewee No. 4 supported the opinion of Interviewee No. 1 and highlighted that other hazards such as fire could easily arise after an earthquake due to dated gas line and power supply infrastructures. Interviewees unanimously agreed that the only means of reducing the current vulnerability of Tehran's antiquated areas would be though reconstruction initiatives and reformed urban planning policies.

4.5. Action Research Method

A valuable component of disaster management planning is the reduction of earthquake risk through the retrofit of existing buildings to achieve increased seismic resistance. This section shall present the author's utilization of the action research method demonstrated through a case study conducted by the author in Tehran in 2014 to evaluate, identify and implement the most appropriate solution for either the reconstruction of a new building or the retrofit of an existing building to achieve increased seismic resistance to address the following research question:

Question (A-b): What are the opinions of Tehran's engineering community in regards to which buildings should be reconstructed or retrofitted and how?

Tehran Case Study (2014): An existing four-story residential building located in the Niavaran area of District 1, northern Tehran. The building was constructed 25 years ago with a structure consisting of a partial steel frame.

Phase 1: Problem Diagnosis: The initial phase of the action research approach was to diagnose the problem based upon our inspection of the building and information provided to us by the owner. The superstructure of the subject building, although constructed with a partial steel frame, consisted of only a few basic girders connected to a limited number of columns, without any bracings or sufficient internal load-bearing walls. The building's owner employed the services of the author's engineering firm in order to assess the structural stability of the building against the latest seismic codes and to determine whether or not the building would be safe for habitation when subjected to lateral loads during an earthquake. Moreover, if the building was found to be unsafe, what engineering solutions could be implemented to increase the building's capacity to withstand an earthquake? Therefore, the research objective was to identify the most time and cost-effective solution to increase the structural stability of the building thereby reducing seismic vulnerability.

Phase 2: Action Planning: The second phase of the action research approach was to develop an action plan based upon theoretical premises to solve the identified problem. Due to the myriad of potential solutions and inherent variables which may perplex the researcher, the problem was classified as a wicked problem requiring in-depth analysis to explore all possible solutions and alternatives. Hence, the qualitative research method would be implemented by means of group interviews held between the author and selected engineering colleagues to assess which potential solution would be most suitable for achieving the research objective. The group interview technique was an appropriate means of ensuring that the research problem and potential solutions were explored thoroughly from multiple perspectives and that more efficient alternative solutions had not been overlooked. Over the course of several group meetings, the research problem was divided into three fundamental questions to be further investigated.

The first question was "***Does the existing structure require improvement in order to withstand seismic loads?"*** In order to answer this question, the researcher composed a schematic model of the existing structure and evaluated its seismic performance through static and dynamic analysis methods. The analysis definitively indicated that the existing structure would fail if subjected to an earthquake of 6.0 Richter magnitude or above and that the building had not been designed in compliance with any current or former seismic codes. Hence, the existing structure did require improvement by means of strengthening crucial structural elements which would serve to increase the seismic resistance of the building.

The second question was: "***Would it be better to retrofit the existing building, or to demolish the building and reconstruct?"*** In order to answer this question, the researcher compared the characteristics of the existing building with the financial costs and time required to either retrofit the building or to demolish the building then reconstruct. Comparison Table 4-7, as presented below, indicated that strengthening of the existing structure would be over 40% more financially economical than it would be to demolish and reconstruct and that the time required to retrofit the existing structure was 9 months versus 18 months required to reconstruct the building. Furthermore, the age of the existing building was 25 years, and the building has been kept in reasonable condition, therefore, it did not truly require demolition and reconstruction.

Table 4-7: Comparison Table for Retrofit of the Existing Structure or Reconstruction of a New Building

Subject	Retrofit of the existing Structure	Reconstruction of a new Building	Contrasts
Cost Implications	**1,138,251 $USA**	**2,732,240 $USA**	**41.66% cheaper**
Time Table	**9 months**	**18 months**	**50 % faster**
Architectural Flexibility	**The plan is fixed, and some proposals would not the feasible.**	**There is full flexibility to design new plan from end to end.**	**Both options are accepted by experts.**

The third question was ***"which type of retrofitting system is more practical and economical?"*** Once the retrofit approach had been determined as the most suitable engineering solution to increase the building's capacity in withstanding an earthquake, several different retrofit methods appropriate for steel structures were discussed in the group meetings. These methods included the use of high-performance non-metallic materials such as reinforced polymers (FRP), jacking beams and columns, additional bracing, additional shear walls, and buckling-restrained braced (BRB) frames, which were studied by many researchers (e.g. Mahdi and Mahdi, 2013; Shafei et al., 2008; Aboutaha and Jirsa, 1996). As a result of the group evaluation, it was determined that the existing structure required extra bracings, fortification of the majority of the existing columns, and the strengthening of existing jacking beam-to-column connections.

Phase 3: Taking Informed Action: Taking informed action is the process of implementing the planning actions outlined in Phase 2. The most suitable locations to affix the proposed bracings were identified through analysis of the schematic modelling. An Advanced Composite Material (ACM) bracing method was selected due to its reasonable economic cost and ease of installation within steel structures. Additionally, steel jackets were selected to be adjoined to the existing columns in order to improve ductility, energy dissipation and enhance the overall column strength. In the absence of an adequate bracing system in the building, ensuring that beam-to-column connections are rigid would be an effective means to satisfy seismic performance. The most conventional type of beam-to-column connections used in construction within Tehran is known as Khorjini connections which provide low rigidity due to the nature of their design. According to research conducted by Shafei et al., in the city of Tehran, "*The structural system of all studied buildings follows the common practice of construction of steel buildings, which have no bracing system, and their connections are Khorjini connections*." (2008, p.7). The existing Khorjini connections, therefore, required retrofit by means of adding two vertical plates, hereafter referred to as "R-plates" perpendicular to the direction of the frame. Please see the upgraded Khorjini connection in Figure 4-33.

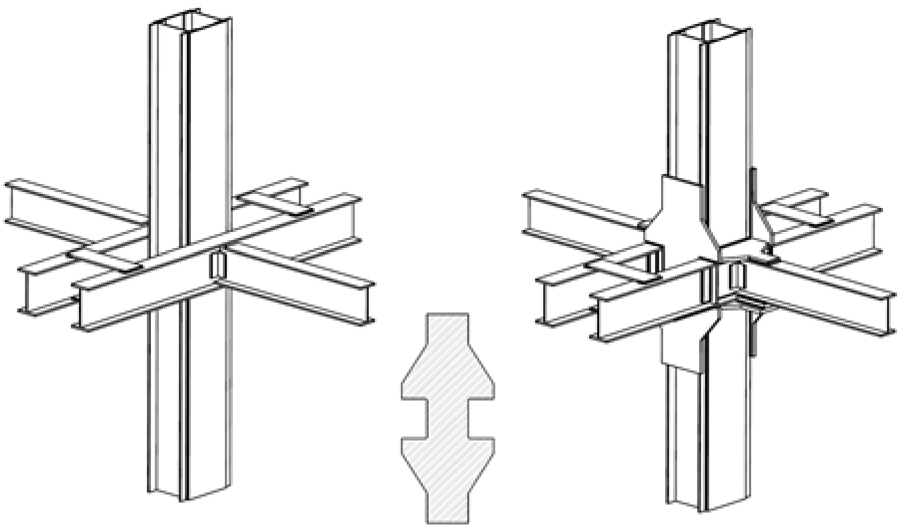


Figure 4-33: Existing Khorjini connection before upgrading (Left). Proposed vertical plate (R-plate) at both sides of the connection (right) (**Shafei et al., 2008, p.4).**

Phase 4: Fact-Finding: The modification works were commenced and executed professionally including the installation of ACM bracings at the predetermined locations along with the installation of steel jackets where required. R-plates (vertical plates) were successfully affixed to both sides of the existing beam-to-column connections. However, during the process of executing the modification works, the team was met with several complications such as the discovery of architectural discrepancies and also challenges relating to the temporary evacuation of residents, some of whom were resistant to leave their homes to allow for the performance of retrofit works. It was discovered that some of the existing columns had not been constructed based upon the design drawings and that revisions had been made during the execution of construction without having been implemented into the final drawings. These discrepancies created complications with the initial retrofit design and obligated the team to modify the design as per the revised column locations. Furthermore, it was observed that some beam-to-column connections had poorly executed workmanship and had been improperly welded during construction. Damage to beam-to-column connection welds in steel moment resisting frames would result in the poor performance of the moment connection and increased when subjected to seismic forces.

Phase 5: Evaluating and Re-planning: After the modifications had been completed the structural model was reanalysed based upon the new findings and the author, as the inside researcher, and team evaluated the outcomes through the several meetings. The outcomes indicated that further steel jackets were required to be applied to the other existing columns that had not been retrofitted and that the application of further bracings was necessary. Furthermore, strengthening of the beam-to-column moment connections was also required. Thus, it was planned to provide additional welding to the bottom haunch of the newly added R-plates and also to re-weld the existing low beam flange grooves welds. The details of this new design were provided to the contractor and executed at the site.

Phase 6: Specifying Learning: After execution of the revised plan the phase of specifying learning is formally undertaken; the specifying learning phase is often a continuous process. Knowledge gained during action research is typically classified into three categories (Azhar et al., 2010). Type 1: knowledge is new practical knowledge acquired during the research, which is commonly referred to as double-loop learning; Type 2: knowledge is any additional knowledge gained as a result of an unsuccessful change; Type 3: knowledge is the scientific knowledge acquired resulting from change and reflection upon the success or failure of action taken. The action research component of this study was successful in generating type 3 knowledge. This scientific knowledge shall be presented in chapter five and form a part of the research findings and recommendations.

The action research process provided several results in the case study as follows:

First: The existing building had not been designed or constructed in compliance with the appropriate seismic codes, however, if the building was designed based upon former seismic codes, it did not comply with contemporary seismic standards. This statement is justifiable as seismic codes have frequently been revised over the last twenty years. Furthermore, as a result of the design evaluation, it was determined that the Iranian seismic code (2800) not be sufficient to withstand the forces of an earthquake with a magnitude greater than 6.0 Richter as opposed to the UBC 97 code or American codes.

Second: There were certain properties within the architectural and structural plans of the building which led to the building's classification as a weak-story building. These types of building are structurally weak as they are vulnerable to ground excitations due to their low levels of resistance and stiffness (Kirac et al., 2011). The Iranian seismic code (2800) requires the construction of continuous columns and shear walls. However, this particular building contained several columns and shear walls which had been discontinued within the structure thereby causing the reduced stiffness of the building.

Third: The poor quality of construction materials used in the building resulted in the building's increased vulnerability to potential damages sustained during an earthquake of a magnitude greater than 6.0 Richter. For instance, inadequate quality construction materials such as brick or masonry infill walls, which are structural panels placed within a bounding frame of a steel building, were found within the existing building and would perform poorly if subjected to the forces of an earthquake. Furthermore, heavy roofing and flooring materials have been used in the building which placed further stress on the already compromised integrity of the structure. Although high-quality construction materials may be expensive, they have a significant influence on increasing the overall strength of a structure.

Fourth: The research results confirmed that there was an absence of engineer supervision of authority inspections during the construction of the building. The results also indicated that the building was not constructed to include certain safety ordinances such as building management systems. Performance-based construction, in which construction engineering services and quality control measures play key roles in earthquake safety, can significantly reduce disaster risk. The performance of effective construction supervision, which includes an array of inspection methodologies to assess the quality of welded construction in steel buildings, was implemented either poorly or not at all in the existing building.

Fifth: No final as-built drawings were available in either the records of the municipality or of the design consultant. Several changes had been implemented in the building design during construction without any party having taken any records. Furthermore, there were no documented records available pertaining to the maintenance or repair of the building or its infrastructure services since having been occupied by residents.

Conclusion: The results verified that a retrofit of the existing structure was the most practical and economical solution to increase the building's capacity in withstanding the forces of a potential earthquake.

4.6. Combined Qualitative and Quantitative Method – Triangulation Method

This section shall exercise the combined qualitative and quantitative research method, referred to as the "triangulation method" (Jick, 1979), to analyse the primary data collected through semi-structured interviews and survey questionnaires against the secondary data collected through literature reviews. A researcher may utilize this method to determine any similarities or divergences which occur in the research findings compared with previous research and to determine any differences between the results obtained by the qualitative and quantitative methods. Hence, the triangulation method enables the researcher to identify any discrepancies and ultimately improve the validity and reliability of the research.

Both the primary and secondary data indicates that Tehran is prone to the occurrence of significant hazards whether natural or human-made. Earthquakes as natural hazards along with vehicular accidents and air pollution as human-made hazards are widely acknowledged as the three primary hazards which currently threaten the welfare of Tehran's inhabitants. Tehran, with a population in excess of ten million, is the most populated city in Iran and one of the most populous cities internationally. As the nation's capital, Tehran is at the centre of economic, social, political and military activities. The city also contains a number of land use categories. Due to the city's diverse spectrum of land uses categories and variety of building types coupled with

Tehran's dense population, a significant risk of disaster and heightened vulnerability is generated, particularly so in the context of an earthquake.

The qualitative and quantitative research methods conducted in this study corroborate that Tehran's disaster risk and its associated negative impacts could be substantially reduced if the city is able to increase its capacity to cope with earthquake disasters through the development of effective disaster management strategies and the implementation of risk reduction measures. Furthermore, both research methods highlight that one of the most practical strategies for the enhancement of Tehran's earthquake hazard coping capacity is to regulate the role of engineering communities within the construction industry and to construct earthquake resistant buildings and infrastructures to enhance the safety of the built environment. Therefore, except for a few cases, we can acknowledge that the results obtained from both the qualitative and quantitative methods are in correlation which demonstrates the validity of the research. The findings obtained through both research methods shall be explained in chapter five to highlight the correlation and validity of the findings further.

One such exception in the results of the research was obtained from the action research component of this study. The results obtained from the semi-structured interview and information sourced from the literature review indicate that the reconstruction of new buildings after the occurrence of an earthquake disaster is the most practical, economical and cost-effective method as opposed to the retrofit of existing buildings for the purposes of seismic resistance. Whereas the results obtained from the action research component of this study, based upon the case study conducted by the author's engineering firm, indicate that the retrofit of existing buildings for the purposes of seismic resistance the most practical and economical method as opposed to the reconstruction of new buildings after the occurrence of an earthquake. Furthermore, the action research findings show that the strategy of waiting for an earthquake to occur and then initiating reconstruction would not enable Tehran's society to cope with an earthquake as it would essentially be required to consent to the risk of massive damages and losses prior to any redevelopment taking place. There would also be further risk that the recovery phase may not be possible to implement in the immediate period after an earthquake event due to the inaccessibility of certain city districts in the aftermath of widespread structural collapse, coupled with the non-availability of reconstruction funding as the majority of losses would not have adequate insurance coverage.

Conclusions & Recommendations

- Chapter 5

CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

5.1. Introduction

This chapter presents the key findings obtained by this research and provides recommendations for the improvement of Tehran's construction industry policies, practices, and standards. Furthermore, research limitations and suggestions for future research shall be discussed prior to the author's last words.

5.2. Summary of Key Findings

In this section, valuable research findings discovered in chapter four shall be discussed in further detail which will enable the readers to better understand the results obtained by this research. These findings are based upon the analysis of primary data collected via quantitative questionnaires, qualitative interviews, observations and personal experience, and secondary data collected via the review of literature such as peer review articles, publications, annual reports and news sources. The following results are categorized based upon the research questions presented in chapter three and shall illustrate the role of construction practitioners in reducing the risk of earthquakes in Tehran.

5.2.1. Part 1: Earthquake Disaster Awareness and Preparedness by Construction Practitioners

The key findings presented in this part pertain to the level of awareness and preparedness of construction practitioners in Tehran and shall address the following research questions:

Questions:

(A-a) Are construction practitioners aware of the significance which earthquake vulnerability plays upon social harm in the city of Tehran and to what extent are construction practitioners prepared to deal with an earthquake hazard?

Key Finding # 1:

The research results show that although construction practitioners in the city of Tehran are aware of the impacts of seismic hazards, there is an urgent need for regularly scheduled seminars in order to provide an environment within which construction practitioners are able to discuss professional issues and provide a channel through which to increase the level of awareness and preparedness of the engineering communities. Mehdian et al. (2004) state that it is necessary to increase the knowledge of construction practitioners and local government employees. It is necessary to understand that increasing the resistance of buildings against seismic forces is an important step towards increasing the overall capacity of the city in dealing with a disaster scenario. The awareness and readiness of construction practitioners play an important role in this regard, hence, it is essential to ensure that professional institutions are actively working towards advancing the knowledge and skills of engineers in the latest technologies and standards for seismic resistant building design and retrofit methods. Amini Hosseini (2008) highlights two essential components of the preparedness phase which have influential roles in earthquake risk reduction including (1) the promotion of public awareness and education, and (2) establishing a culture of awareness and self-protection within construction practitioners' communities.

The research results indicate that there are a large number of unskilled workers and unqualified engineers employed within Tehran's construction industry. Existing literature also states that a significant proportion of Tehran's low-quality construction is due to a lack of skilled workers and unqualified engineers (e.g., Tabassi and Abu Bakar, 2009; Ghafory-Ashtiany and Eslami, 1997; Akhavan, 1998). In addition, the results indicate that a substantial number of existing buildings were built over thirty years ago by non-specialist construction practitioners. Therefore, these findings substantiate the statement that Tehran's construction industry has in the past been under the supervision of non-professionals who did not possess comprehensive knowledge of seismic codes. This study identifies the two primary reasons for which non-specialists have a tendency to participate in the construction industry namely: (1) the economic weakness of other industries, and (2) the substantial financial returns and benefits offered by the construction industry.

Questions:

(A-c) *Are construction practitioners aware of which types of structures are the most vulnerable to the impacts of seismic forces and what problems must be addressed to reduce the vulnerability of these structures?*

(A-d) Are construction practitioners aware of how the quality of construction materials can influence the seismic vulnerability of a building and what problems may prevent the use of high-quality construction materials?

Key Finding # 2:

As per the quantitative questionnaire and qualitative interviews, the research results indicate that Tehran's construction practitioners are aware that the seismic vulnerability of structures depends upon certain factors such as the age, type, and height of buildings in conjunction with the type and quality of construction materials utilized. These factors are evident in literature which also confirms that the age of buildings and infrastructure (e.g., Zolfaghari, 2006), and the type of materials used in construction and the stability of structural elements against seismic forces are critical factors which influence the vulnerability of structures during earthquakes (e.g., Arian et al., 2012; Naderzadeh, and Moinfar, 2004; Amiri et al., 2003). This study confirms that the factors which contribute to the instability of structural elements within many buildings across the Tehran are:

1) **The Age of Buildings**: Zolfaghari (2006) underlines that the age of buildings and infrastructure is an important factor which contributes to the seismic vulnerability of a built environment. The research shows that more than 70% of Tehran's existing building was constructed over thirty years ago. A vast majority of buildings constructed over thirty years ago were not designed in accordance with seismic codes, those which had been designed in accordance with former seismic codes no longer achieve seismic safety standards as these seismic codes have been repeatedly revised and improved over the last three decades. This means that buildings which were designed thirty years ago as per the inadequate former seismic codes would not be safe for human occupation during an earthquake as per the current seismic codes; this is also the case for the quality building materials utilized in the construction of buildings.
2) **The types of Buildings**: The research results show that a majority of buildings constructed within Tehran are unreinforced masonry (URM) buildings with semi-metal frames which offer poor seismic resistance. Numerous researchers (e.g., Zolfaghari, 2006; Naderzadeh and Moinfar, 2004; Ghafory-Ashtiany, 1999) stress that over seventy percent of buildings in Tehran are unreinforced masonry (URM) buildings. Unreinforced masonry (URM) buildings commonly constructed with steel frames in which columns and beams are connected by a type of connected referred to as Khorjini connections in the local language as explained by Naderzadeh and Moinfar (2004). Khorjini connections consist of posts supported by saddle beams with further support being provided by angle profiles, hence,

the widespread existence of structurally unstable URM buildings is a primary concern which must be addressed in order to reduce the seismic vulnerability of buildings in Tehran. Key (1995) clarifies that URM buildings are not eligible to be classified as seismic resistant buildings. Furthermore, URM building do not satisfy the requirements of Iranian Seismic Code (2800). An example of why URM buildings are not eligible to be classified as the seismic resistant building, as stated by Naderzadeh and Moinfar (2004), is that their column ties and beam ties are often non-existent at the foundation level which directly violates lateral seismic force design requirements.

Managing the earthquake risk of Tehran's abundance of unstable URM buildings is a challenging and arduous undertaking. Many construction professionals have provided successful solutions to reduce the risk of earthquakes by enhancing the structural stability of URM buildings. One such strategy is to strengthen existing URM buildings by adding ties and bracings which can significantly reduce structural deformation when subjected to the lateral loads generated by earthquakes (Naderzadeh and Moinfar, 2004). Fortunately, many of Tehran's buildings, even those located in the city centre, are detached buildings, meaning that they do not share common walls with other buildings and have sufficient space around the perimeter of the external walls to allow for the installation of external bracings and additional foundations. This strategy has been implemented by the author's engineering firm in many buildings across Tehran as discussed in chapter 4 and will be explained further in this chapter.

3) **The height of the Buildings**: The disregard of URM building height limits is another factor which contributes to the structural instability of many buildings across Tehran. A majority of existing URM buildings in Tehran are in excess of two stories with structures poorly connected to unreinforced masonry walls. As per the Iranian Building Code (2800) introduced in the late 1960's, masonry buildings should be constructed with ties and to a height not exceeding two storeys, however, as per the investigation conducted by Naderzadeh and Moynfar (2004) into buildings constructed in Tehran since 1980, it was discovered that many URM buildings were constructed without any horizontal or vertical ties and that the height of buildings commonly exceeded two storeys. A majority of existing building across Tehran's 22 districts consist of un-tied masonry structures

exceeding two storeys in height which would not be structurally stable if subjected to the forces of an earthquake.

4) **The quality of building materials and structures**: The research results show that there are a high number of buildings in Tehran which are vulnerable to earthquakes due to the low quality of structural elements and poor quality of building materials. The research results show that northern districts such as Districts 1, 2 and 3 have been constructed with high quality materials and workmanship, while Districts 4, 5 and 6 have been constructed with good quality materials and workmanship, and the remaining districts suffer from the use of moderate to low quality materials and workmanship in their construction. This study identifies the three primary reasons for this issue namely: (1) the unavailability of certain high-quality construction materials and systems, (2) financial constraints and a lack of funding, and (3) ethical shortcomings such as the planned utilization of low-quality inexpensive materials with intent towards obtaining higher profits.

Questions:

The results presented in key finding number 2 show that a majority of Tehran's existing buildings do not have the capacity to cope with the forces of a strong earthquake, therefore, the following question should be answered.

(A-b) What are the opinions of Tehran's engineering community in regards to which buildings should be reconstructed or retrofitted and how?

Key Finding # 3:

The distribution of population varies across the Tehran's 22 districts, and the existence of fault lines in these areas determines how many people would be affected in the event of a major earthquake. Furthermore, the quality of the built environment and urban planning can determine the scale of an earthquake's impacts. Results obtained from the quantitative survey and literature review (e.g., Arian et al., 2012; Naderzadeh, and Moinfar, 2004; Amiri et al., 2003) indicate that there are a significant number of vulnerable buildings in Tehran under threat from the impacts of a disaster due either to the inaccessibility of the buildings, unstable structures, the small size of roadways versus the height of the buildings, or a combination of these factors.

The research results indicate that Tehran's ratio of worn texture to total area is more than 10% in some central and southern districts such as Districts 7, 8, 10, 11, 12, 14 and 17. The results also indicate that there are a significant number of old buildings above thirty years of age in the central, eastern and southern regions of the city including Districts 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17. Building reconstruction and building retrofit are the most pertinent solutions to reduce the destructive impacts of earthquakes (e.g., FEMA, 2015; FEMA, 2008) in worn texture environments. The research results show that a majority of buildings in all of Tehran's districts require either reconstruction or retrofit in order to achieve acceptable levels of seismic resistance earthquakes as is confirmed by literature (e.g., Naderzadeh, and Moinfar, 2004). The results further indicate that although the government does provide some regulatory support for the retrofit of existing buildings, the level of renovation is very low in the older and most vulnerable parts of the city such as Districts 9, 10, 11 and 12.

Key Finding # 4:

Another key finding of this research is related to the financial constraints surrounding the reconstruction or retrofit of buildings and determining who is financially responsible for the construction costs of such undertakings. Should the funding be provided by developers or will the government grant such funding? Naturally, landlords are not willing to provide this funding as there is no financial incentive to do so, while the end-users or tenants may be motivated to increase the structural stability of their residences but may not have the financial capacity to do so. Furthermore, due to the poor performance of the insurance sector over the last two decades and a lack of clearly defined insurance policies within the real estate sector, a majority of the general public does not have confidence in the security of the insurance market or its ability to provide effective coverage over the impacts of natural disaster. Literature also indicates that insurance schemes are not commonly sought by Tehran's general population (Zolfaghari, 2006).

The research results support arguments made by Amini Hosseini et al. (2013) and Vaziri et al. (2010) and indicate that the primary source of financial funding for the reconstruction or retrofit of structures for the purposes of increased seismic resistance is provided either through government loans or government grants. Therefore, the financial responsibility for the retrofit of existing buildings before an earthquake or the reconstruction of new buildings after an earthquake ultimately remains with the government. This may force the government to divert or cease funding from other development projects listed in the city's development plan budget intended for other purposes in the geater metropolitan program. Alternatively, the government has been seeking additional support from international donors, an act which in itself may create further political controversies. Financial constraints are not only a major issue in the development of seismic resistant built environments but also serve to limit the usage of high-quality materials in all levels of construction, ultimately influencing the overall quality of finished buildings. An important step required to be taken in this regard is the allocation of specific funding for the retrofit and reconstruction of buildings; which is a worthwhile policy and a significant contribution towards increasing the seismic resistance and construction quality of buildings. The strategy of retrofitting buildings for the purpose of increased seismic resistance is a common practice, however, in some cases may become more expensive than total reconstruction as argued by Moore (2000). This statement shall be discussed in the action research section of this chapter in further detail.

Questions:

Since old infrastructures can increase the risk of sustaining greater earthquake impacts, there are some basic questions which should be asked relating to the current condition of infrastructures in Tehran and the reduction of earthquake risks.

(A-b) How the existing infrastructures and lifelines should be improved?

Key Finding # 5:

The research results indicate that old infrastructures such as gas distribution networks, electricity distribution networks, and indirect urban services can significantly increase the risk of sustaining greater earthquake damages. Amini Hosseini and Jafari (2007) argue that the city of Tehran has a high overall vulnerability to earthquakes due to the considerable vulnerability of old infrastructures within the city. In consideration of the quality and quantity of Tehran's lifelines, urban services and facilities it is evident that the central and southern districts of Tehran are most vulnerable to the failure of emergency services and evacuation planning as opposed to the northern districts of the city. Furthermore, the suburban areas of Tehran have less overall access to urban facilities than the other districts of the city. The distribution of built-up areas versus open spaces differs among the various districts. The research results indicate that the western suburban districts such as District 22 have the highest ratio of green and public spaces which could be utilized for the mass emergency care and sheltering of disaster victims, whereas central districts such as Districts 10, 11, 12 and 17 have the least green or public spaces available for these activities. In the context of urban planning and development, the central and southern districts of Tehran are the most vulnerable to the impacts of an earthquake. Hence, the question remains of how to best reduce the risks of urban planning problems and old infrastructures in the southern and central districts of Tehran. The research results indicate that government authorities have the most critical role to play in the management of urban development problems. They must seek practical solutions to enhance the urban development of the city such as improving worn textures and old infrastructures (e.g., Ghafory-Ashtiany, 2006), increasing the width of narrow roadways and rectifying the poor access problems present in the vulnerable districts (e.g., Amini Hosseini and Jafari, 2007).

5.2.2. Part 2: The Role of Construction Practitioners in Earthquake Risk Reduction:

In this section, key findings relating to the role of construction practitioners in the reduction of seismic impacts are presented, and the following questions are addressed:

Questions:

(B-a) To what extent to do engineers and supervisors have knowledge regarding seismic design and practice codes?

(B-b) Do construction practitioners regularly update their knowledge of standards and regulations of construction practice in relation to seismic codes and ductile detail requirements?

Key Finding # 6:

Engineers have the highest capacity to reduce earthquake impacts by implementing seismic codes and construction regulations during all stages of construction to create buildings which are resistant to the forces of earthquakes. Literature highlights the role of professional engineers in the mitigation of death, damage and other negative consequences associated with earthquake hazards though the improvement of buildings (e.g., Mohorovcic, 2009; Bozorgnia and Bertero, 2006). Any decision made by developers to either ignore the instruction of engineers, not accept the authority of municipal engineers during construction monitoring, or to insist upon unethical practices in order to achieve higher profits ultimately serves to reduce the quality of buildings and increase earthquake vulnerability. Engineers can also reduce the impacts of earthquakes by complying with the standards of building safety and management systems such as fire-fighting and fire-alarm systems which can prevent the spread of potential fires caused by earthquakes (e.g., Geschwind, 1996; Mousavi et al., 2008; Bozorgnia and Bertero, 2006). It is evident that fire safety in buildings plays an important role in reducing the impacts of an earthquake and reducing the overall risk of disaster impacts.

The research results indicate that the level of knowledge and skill of engineers which have graduated from universities in Iran is insufficient to properly implement seismic risk reduction measures. There are many universities in Iran responsible for the education of future engineers in modern the engineering techniques required for the development of seismic resistant built environments. Earthquake engineering is a relatively new discipline which requires being frequently updated, therefore, ensuring that Iranian engineers are kept up-to date in the latest earthquake engineering techniques is critical. Unfortunately, the research results indicate that, due to inadequate academic standards, a graduate engineer often do not possess the necessary technical knowledge and are not well prepared to confront an earthquake; the presence of unskilled engineers within the construction industry is a common problem which affects all of Tehran's districts (e.g., Ghafory-Ashtiany, 1994; Manafpour, 2003).

Questions:

(B-c) *Are there any professional entities such as a civil engineering society or earthquake engineering association from which construction practitioners could obtain updated information on a regular basis?*

(B-d) *How often do engineers participate in training classes or seminars conducted by professional entities?*

Key Finding # 7:

While, literature (e.g., Ghafory-Ashtiany et al., 2000) suggests that specialized training on advanced topics in practical aspects of earthquake engineering has led engineers to more toward earthquake engineering and seismic design and construction, and graduate studies in earthquake related fields were established in different universities in Iran. The research results indicate that, apart from a few institutes and universities, most Iranian educational institutes and universities have not conducted much research pertaining to the subject of earthquake engineering and that any research which is done is often not reported to engineering specialists. The research findings also show that there is no well-established connection between alumni engineers and the universities or institutions from which they have graduated, which may further contribute to deficiencies in construction engineering knowledge and engineering innovation. Engineering graduates mostly assume that they do not require any more academic study after having completed their degrees and that they will be able to solve all of the engineering problems faced during their career with the training which they have received. The question remains as to why the level of technical knowledge and skill of Iranian engineers is not compatible with effective earthquake-resistant construction.

5.2.3. Part 3: The Role of Laws and regulations in Earthquake Risk Reduction:

In this section, key findings related to the role of rules and regulations in earthquake risk reduction and urban planning are presented, and the following questions are addressed:

Questions:

(C-a) *Is there any intent to enhance Tehran's urban planning to reduce vulnerability and the impacts of future seismic events? To what extent do the current construction regulations support this plan? What is the responsibility of construction practitioners in this regard?*

Key Finding # 8:

Tehran's geographic proximity to numerous active fault lines is a major factor which contributed to the high earthquake vulnerability of the city, however, there are additional factors which must be considered in assessing the vulnerability of the city such as population density and the distribution of vulnerable demographic groups such as children and the elderly. Lai et al. (2016) emphasize that children, the elderly and disabled persons are the most vulnerable to the health impacts of disasters and that the distribution of these impacts is not uniform amongst the affected peoples. The regions of Tehran most vulnerable to the impacts of earthquakes due to fault line proximity are primarily the northern, north-eastern and north-western districts including Districts 1, 2, 3, 4, 5 and 22, and the southern and south-eastern districts including Districts 15, 16, 19 and 20. The regions of Tehran most vulnerable to the impacts of earthquakes due to the population distribution of vulnerable age groups such as children between the ages of 0-14 years and the elderly above the age of 65 years are primarily the northern and north-western districts including Districts 1, 2, 3, 5 and 22, and the southern and south-eastern districts including Districts 15, 16, 18, and 20. The regions of Tehran most vulnerable to the impacts of earthquakes due to highly concentrated population densities and primarily the central districts including Districts 10, 11, 12 and 17, and the eastern districts including Districts 7, 8 and 14. In consideration of the above factors, it can be deduced that the most vulnerable districts of Tehran are situated in the northern and southern regions of the city, followed by central, eastern and western regions respectively.

Urban expansion in the northern and southern regions of the city is limited due to topographic and geographic factors, therefore, urban expansion is more logical and practical in the western regions of the city, which is also the region least vulnerable to the impacts of earthquakes. However, the research results indicate that the highest concentration of urban development over the last four decades has been in the north-western, and north-eastern districts of the city including Districts 2, 4, 5 and 8 which has led to an increase in the vulnerability of the population as these districts are directly located along active fault lines. Literature supports a similar argument (e.g., Ashtiani and Amini Hosseini, 2005; Arian et al., 2012). This indicates that the Tehran Municipality has not succeeded in regulating urban development and population growth in hazardous areas. Despite the Tehran Municipality being aware of the dangers of urban development in hazardous areas, they have continued to issue new building permits in these areas regardless of the elevated risk.

Key Finding # 9:

In regards to the accessibility of public services and facilities such as fire-stations, police-stations, hospitals and ambulance services, there is a discrepancy between the information provided in the primary data and the secondary data. According to the primary data, the northern districts of Tehran have better access to public services and facilities in comparison to the central and southern districts. However, according to the secondary data including litrature (e.g., Hosseini, Mohaymany, and Movini, 2006; Hosseini and Amini Hosseini, 2008), it is the central districts which have better access to the same public services and facilities. The personal experience and observation of the author can help to explain this discrepancy. As the central districts are the main body of the old city, public services and facilities in these areas have been well developed and improved over time, whereas, the northern areas of the city benefit from a more modern approach towards urban planning in terms of roadways, bridges, infrastructure distribution systems and well allocated public services and facilities such as hospitals and public transport networks. As such, it can be concluded that both the central and northern districts of

Tehran benefit from better accessibility to public services and facilities in comparison to the western, southern and eastern districts of the city.

Based upon the above evaluation and in accordance with Key Finding # 8, it can be deduced that urban expansion and the enhancement of public services and facilities should be focused towards the western districts of Tehran to provide a full range of requirements for the development of appropriate emergency response plans in these areas. The requirements for effective emergency response planning include rescue services, relief provisions, medical treatment, evacuation planning, emergency traffic management and lifeline security.

There are significant challenges in regards to urban planning in the southern and eastern districts of Tehran, which are highly vulnerable to the impacts of earthquakes due to the unavailability of adequate urban services. In the event of an earthquake, it would prove difficult to provide efficient access to the affected peoples in the southern and eastern districts of the city. Tehran Municipality should allocate the development of new urban facilities for the southern and eastern regions in their master plan, and insist upon implementing these improvements as soon as possible to avoid a substantial disaster in the near future. In the southern and eastern regions of Tehran the average age of buildings is often over thirty years, therefore, it is likely that the authorities are receiving permit applications from building owners to renovate or rebuild these properties. It is during this building permit application process that the Tehran Municipality and local administrations must ensure that these buildings are renovated or rebuilt in accordance with the latest urban planning policies and that all parties involved such as contractors, consultants and owners execute the construction in compliance with the relevant construction standards, regulations and seismic codes.

A further problem relating to emergency and evacuation planning is the poor access due to narrow roadways in the worn texture of the central city districts, as is confirmed by existing literature (e.g., Hosseini, Mohaymany, and Movini, 2006; Hosseini and Amini Hosseini, 2008). In recent years some measures have been taken to improve the worn texture in accordance with Tehran's urban development program, however, there remain a vast number of buildings in these areas with poor access to emergency evacuation zones. Furthermore, the government has not made any significant efforts to reduce the population density in these areas. The combination of high population densities, poor emergency access and narrow roadways in the central districts of Tehran creates a major problem in the provision of mass care and sheltering to the victims of an earthquake. The research results highlight that the government is primarily responsible for providing emergency action plans in response to hazardous events, however, the government's poor performance in responding to previous emergency scenarios such as the Bam Earthquake (2003) indicates that the government is not adequately prepared to provide immediate emergency response to the victims of disaster (e.g., Manafpour, 2003). The negligence of various government entities and lack of coordination between different authorities is the key cause of the government's poor performance in the past.

Questions:

(C-b) Are there any laws and regulations in Tehran's construction industry pertaining to seismic safety or do engineers follow international standards?

(C-c) Are these laws and regulations sufficient to reduce the impacts of an earthquake and have these laws and regulations been frequently updated?

Key Finding # 10:

The research results indicate that although Tehran does have laws and regulations pertaining to the seismic safety of construction, these laws are regulations fall well below international standards. Furthermore, the results also indicate that Tehran's seismic design regulations are in urgent need of reform and improvement (e.g., Government of Iran, 1979, 1989; Ghafory-Ashtiany, 2006). Even if all of Tehran's exiting seismic design regulations are carefully followed, an earthquake of high magnitude would still destroy many of the buildings in the city as the current seismic design regulations have not been sufficiently updated over the last twenty years. Furthermore, the research results suggest that the engineering society should concentrate on the quality of construction execution to ensure that seismic design regulations are actually complied with during construction, rather than focusing solely upon the design stage of construction as is the current norm.

Recently, Iranian earthquake engineers have decided to implement the UBC 97 code rather than the Iranian Seismic Code (2800). One key reasons for this change is that Iranian earthquake engineers have acknowledged that the Iranian Seismic Code (2800) was not adequate for the design of a building intended to withstand an earthquake of 6.0 Richter magnitude since the code provided design criteria based upon static analysis, whereas, International Codes of

Practice declare that the construction of buildings in areas with the potential of earthquakes exceeding 6.0 Richter magnitude must be designed based upon dynamic analysis.

5.2.4. Part 4: The Role of Government and Authorities in Earthquake Risk Reduction:

In this section, key findings related to the role of governments and other authorities in earthquake risk reduction are presented, and the following questions are addressed:

Questions:

(D-a) To what degree would the local government and Tehran municipalities bear responsibility towards the implementation of the required seismic regulations?

(D-b) Is the responsibility of the local government and Tehran municipalities sufficient to manage disaster events and if not, why do they not wish to provide a suitable response?

Key Finding # 11:

The first task for which the government is responsible is to ensure that members of the community are informed about the risk of an earthquake. In this regard, the research results indicate that the government has been successful and that most of Tehran's population is aware that the region is highly susceptible to earthquake impacts; these results correlate with existing literature (e.g., Government of Iran, 1979, 1989). Another responsibility of the government is to develop organization(s) aimed towards improving the quality of buildings by training specialists and by providing comprehensive and integrated regulations. In the last two decades, the government has established two organizations tasked with increasing the disaster coping capabilities of the country as stated by Bakhtiari (2014) ; (1) The Iranian Construction Engineering Organization (IRCEO), and (2) The National Disaster Management Organization (NDMO). A further responsibility of the government is to provide construction practitioners with real training to ensure that they are prepared to take informed action both during an earthquake event and in anticipation of future earthquakes.

Despite efforts having been made by the government to fulfil their responsibilities, their actions have not been sufficient to substantially reduce earthquake risk, and many issues still remain, as is suggested by literature (e.g., Ghafory-Ashtiany, 1999; Ghafory-Ashtiany, 2006; Mehdi et al., 2004). For instance, some engineers who hold positions of responsibility within government departments do not strongly insist upon compliance with seismic construction laws and regulations due to a widespread lack of well-enforced surveillance over supervising engineers by their managers or purely due to their dissatisfaction over their employment on account of poor salaries. Failure to effectively supervise construction and/or incorrectly enforce building regulations often results in poor construction design and execution. The research results exhibit that failures and shortcomings in the enforcement of regulations are most commonly observed during the execution phase of construction and installation of safety systems.

An example of the government's failure to effectively supervise and/or incorrectly enforce building regulations is their approval for the development of building located within fault zones or upon the stable land with poor soil conditions (e.g., Hosseini and Amini Hosseini, 2008). In this scenario, even if buildings are constructed in full compliance with seismic codes they would not have the capacity to withstand a strong earthquake due to their vulnerable location; a danger which the authorities are fully aware of. The government's performance in the monitoring and regulation of construction on unstable lands and fault zones has been entirely unacceptable, evidence for this claim is seen in the existence of high-rise buildings constructed around fault zones in Districts 1 and 22 with the permission of the Tehran Municipality. Furthermore, consultants and architects accept responsibility for monitoring the construction of buildings in hazardous locations without considering that their actions may be endangering lives, while builders and contractors carry out the construction of these buildings in order to obtain profits without being aware of the dangers of the work they are undertaking. Ultimately, the government bears responsibility over the construction of buildings in hazardous areas as it would not be possible in the first place without having provided their approval.

A further example of the government's failure to properly monitor and control construction is the existence of a large number of low-quality construction projects operating without building permits in the countryside surrounding Tehran (e.g., Tabassi and Abu Bakar, 2009; Ghafory-Ashtiany and Eslami, 1997; Akhavan, 1998). Seismic codes express that all structural elements such as columns, beams, shear walls, slabs, and connections should be appropriately inspected by a qualified engineer who is aware of all regulations and standards. For instance, in the city of Dubai, U.A.E., the inspection of construction is conducted not only by qualified engineering consultants but also by Dubai Municipality engineers in order to verify that structural elements have been provided in accordance with the relevant seismic codes. These types of inspection are mandatory even during the construction of one-storey structures such as warehouses, residential homes, and parking shades. A significant problem in the development of seismic non-resistant buildings in Tehran is the inability to effectively enforce construction laws due to the absence of adequate construction supervision and the non-performance of professional standards during the inspection, as literature also highlights (e.g., Arian et al., 2012; Amiri et al., 2003).

The power of landlords, whose agendas influence the decisions of engineers, is another significant obstruction in the enforcement of laws and regulations. The primary goal of landlords is to maximize profit margins, therefore, they often persuade engineers to design structural elements below seismic code requirements and to influence contractors to execute the construction in a particular manner which reduces costs to increase their end-profit margins. Unfortunately, construction professionals often cooperate with the requests of landlords in order to achieve higher profits themselves or even out of fear for losing their jobs; this is an unethical practice driven purely by profit and a substantial threat to Tehran's construction industry and population. Furthermore, the lack of coordination between the Iranian Construction Engineering Organization (IRCEO) and the Tehran Municipality, acting as the inspection authority and the administration authority respectively, results in the failure of monitoring regulations further enabling the unethical practices of certain parties to continue unchecked.

5.2.5. Part 5: The Role of Ethical Practice by Construction Practitioners in Earthquake Risk Reduction:

In this section, research findings related to the role of ethical practice in earthquake risk reduction shall be presented, and the following questions are addressed:

Questions:

(E-a) To what extent do construction practitioners in Tehran feel that ethical practice is an essential component of their profession and are these professionals involved in any form of corruption or bribery which may compromise the quality of construction works?

*(E-*b) *Are there any ethical rules related to the construction of buildings in areas of high risk and are there any ethical codes of practice to guide construction practitioners in this respect?*

Key Finding # 12:

The research results indicate that bribery and corruption which compromises the quality of construction works exist within Tehran's construction engineering community. Zolfaghari (2006) purports that corruption and a lack of clear procedures regarding unethical behaviour are the primary reasons why construction engineers in Tehran often turn a blind eye to the regulations. Construction engineers in Tehran often do not receive adequate remuneration for their professional services when compared with the salaries of their counterparts in other nations, this combined with the fear of losing one's employment if seen to be challenging the status quo within the industry results in a susceptibility to bribery or corruption. Hence, construction engineers operating in this environment may be inclined to commit unethical practices which ultimately result in the violation of construction codes and regulations; this problem is also identified in literature (e.g., Kahn et al., 2005; Daftari cited in UN, 2004). The research results also indicate that engineers in Tehran do not perform thorough inspections during the course of construction. The primary cause for this lack of stringent inspection being the meagre salaries of the supervising engineers, which when coupled with the authority of the engineer's professional status creates an opportunity for bribery such as providing work approvals in exchange for money rather than based upon the quality of the work itself. King et al. (2008) state that unethical behaviour can negatively impact the performance of the profession.

Another problem within Tehran's construction industry is the system of issuing work inspection approvals. Primary checklist inspections are commonly conducted by an individual engineer rather than by an engineering consultancy firm. Upon conducting the inspection, the engineer, if having deemed the work fit for approval, will sign a stamp an approval slip issued by the Tehran Municipality in the name of the Engineer and provide the contractor with the slip to present in turn to the Tehran Municipality as proof of approval, this slip is known as an "Engineer's Coupon" when translated from the local language. There are two major problems with this system of obtaining works approval: (1) The responsibility of approving completed construction works lies with only one individual rather a consulting firm; this means that the parameters necessary to obtain approval vary based upon the requirements of the individual inspector. Furthermore, if errors are discovered at a later stage, liability lies with an individual who may no longer be available for contact rather than with an established company to which claims could be made against. (2) If an individual is entitled as a decision-maker, rather than a company, certain forms of unethical practice can be expected to occur more often. Therefore, all relevant stakeholders, in particular, the governing authorities, should take action to stop this system of practice and mandate that only established and licensed companies are permitted to undertake the responsibility of construction inspections to ensure that a liable party is available if any violations or offences are discovered.

5.2.6. Part 6: Action Research Approach

In this section, research findings related to the action research component of this study shall be presented, and the following question addressed:

Questions:

(A-b) *What are the opinions of Tehran's engineering community in regards to which buildings should be reconstructed or retrofitted and how?*

Key Finding # 13:

The research results obtained from the action research component of this study indicate that the case subject was not constructed in accordance with seismic codes or standards; this is the case for many buildings across Tehran particularly in the central and southern districts of the city and other regions where the worn texture is prevalent. The research results also indicate that the existing building was at high risk of collapse if exposed to the lateral forces of a 6.0 Richter magnitude earthquake due to poor quality construction supervision and the use of low-quality construction materials. Ghafory-Ashtiany (1999) believes that seismic design, the manufacturing and selection of construction material, workmanship, and inspection are conducted poorly within Tehran's construction practice. The outcomes confirmed that there had not been adequate supervision either by consulting engineers or authorities during construction of the building. Furthermore, no as-built drawings were available for review in either the records of the Tehran Municipality or in the records of the consultant engineer, who was employed as a freelance engineer and no longer available for comment. There were some fundamental changes to structural elements which had not been adequately addressed in the revised design, for example, the position of a number of columns had been modified without then modifying the overall design based upon the new conditions.

5.2.7. Part 7: Conclusion

In this section, a conclusion to address the core research question is provided. The core research question as presented in chapter three is:

To assess the state of awareness and current practice of construction engineers and the construction industry in preparation for seismic events and to explore the contrast between the optimal construction practices versus the current construction practices in the city of Tehran.

The research findings of this study indicate that there are several key factors which undermine the integrity of Tehran’s buildings, lifelines, and infrastructures serving to increase the vulnerability of the city during a potential earthquake. These findings correlate with existing literature (e.g., Vaziri et al., 2010; Zolfaghari, 2006; Hosseini and Amini Hosseini, 2008; Arian et al., 2012; Amiri et al., 2003; Nateghi, 2001; Manafpour, 2003; Mehrabian and Haldar, 2005; Ghafory-Ashtiany et al., 2000; Mehdian et al., 2004; Amini Hosseini and Jafari, 2007; Naderzadeh, and Moinfar, 2004; Moinfar, 2003). These key factors consist of (1) financial issues and a lack of access to insurance policies, (2) the irresponsibility and negligence of construction practitioners and officials, (3) inadequate land-use planning and construction codes, (4) a lack of professional ethical standards during construction, (5) the inadequate knowledge and skills of specialists, (6) incomplete disaster management plans , (7) a lack of regular and continuous review strategies, (8) inadequate supervision during construction works, (9) poor quality design and construction execution, and (10) the utilization of low-quality construction materials.

The implementation of earthquake prevention programs in areas of high seismic risk is necessary to reduce the potential damages sustained during earthquakes; this may be achieved through the development of earthquake-resistant buildings and infrastructures. The research findings outline several suggestions for the enhancement of Tehran’s built environment which would serve to improve the seismic resistance of the city. In accordance with the research findings, further recommendations for the enhancement of Tehran’s built environment are presented below.

5.3. Recommendations

Based upon the data analysis findings, recommendations which could help to enable Tehran’s engineers to identify methods of risk and vulnerability reduction in addition to recommendations for planning and taking action at all levels of decision-making are presented in this section. Although the implementation of disaster management plans is more effective at the preparation and mitigation phases of the disaster management cycle, an effective earthquake risk reduction strategy must be efficiently planned in all phases of the larger disaster management plan including preparation, prevention, response, rehabilitation, and reconstruction.

Recommendation # 1: Role of the Tehran Disaster Management Organization

The Tehran Disaster Management Organization should be fully authorized by the government and Tehran Municipality to act not only during the emergency phase but also in all other aspects of disaster management including the forecasting, monitoring, mitigation, risk assessment, and improvement processes. The parallel operation of various organizations should be avoided during the relief activities of the emergency phase, and a structured crisis management model should be established in partnership with the Tehran Disaster Management Organization.

During the forecasting, monitoring, mitigation, risk assessment and improvement phases, stakeholders such as the government, developers, contractors and other members of the engineering community should operate in compliance with the laws and regulations surrounding the development of built environments to effect the reduction of earthquake risks. The Tehran Disaster Management Organization should be active on a daily basis rather than only during the occurrence of a disaster. Furthermore, they should be in regular contact with professional institutions and universities to ensure that laws, regulations and seismic codes are kept up-to-date with the latest earthquake engineering technologies and standards. Tehran's master urban plan should be updated to meet current emergency response requirements and urban capacity safety limits in certain districts most at risk; it may even be necessary to demolish some existing buildings or not to permit the construction of new buildings in densely populated areas.

Recommendation # 2: The Role of Engineering communities

Members of the engineering community such as architects, designers, supervisors, contractors and other construction related professionals should be familiar with modern earthquake engineering techniques and develop a habit of implementing these techniques in their projects. Existing standards and technical specifications should be revised to improve the seismic resistance capabilities of Tehran's built environment. The employment of trained and qualified workers, the elimination of unskilled construction labourers from the workforce, and ensuring the continuous monitoring of construction works by engineers who are certified by the

Iran Society of Engineering and have experience in the field of earthquake engineering are all measures which can contribute towards the elimination of low-quality vulnerable buildings and infrastructures. Furthermore, the quality of construction works can only be ensured if the responsible engineers, such as Tehran Municipality engineers, conduct regular oversight and inspections over works carried out by contractors and consultants during all phases of construction.

The issuance of penalties such as fines or license suspensions by the relevant authorities upon consultants and contractors in cases of repeated regulatory violations or unprofessional works could help to increase the compliance and performance of supervision engineers during inspection procedures. Additionally, the formation of laws which mandate that all inspections must be conducted by a licensed company and not an individual could serve to reduce corruption within the industry and require professionals to observe standards of practice.

Seismic research centres and seismology institutes should provide extended education programs for construction professionals to ensure that their knowledge is updated regularly in the most recent earthquake engineering technologies and practices. If necessary, examinations for graduate engineers should be held to assess their level of knowledge and skill in designing and constructing earthquake-resistant buildings and infrastructures. The U.K. Civil Engineering Institute (ICE), of which the author has been an active member for the last decade, regularly conducts examinations for members across the world to evaluate the skill and knowledge of engineers. Engineers are not entitled to become active members of the organization until they have successfully completed the examinations; recruiting engineering companies in the U.K. often choose only to employ engineers who are active members of the institute. All ICE members receive issues of a monthly magazine named “New Civil Engineering” which covers various topics such as earthquake engineering, construction operations, and professional ethics.

Recommendation # 3: Professional Ethics

The professional ethics of engineers within the construction industry plays a critical role in the management of corruption. Constructions works cannot be efficiently or professionally conducted if unethical practices such as bribery or corruption are present within the engineering community, therefore, the first step to prevent this problem is to provide construction engineers with the correct ethical information and guidance. Tehran’s engineering institutes are responsible for ensuring that construction engineers are regularly updated regarding the standards and codes of ethics and for reminding them of the potential repercussions of engaging in such behaviour; this practice is regularly conducted by the U.K.'s Civil Engineering Institute (ICE). Universities should implement compulsory courses for engineering students on the subject of professional ethics so that students may become accustomed with these codes of ethics from the outset of their careers. Engineers must be careful not to engage in any unethical behaviour which may compromise the quality of construction works for financial benefit, and they must always be reminded that their work is directly associated with the safety and protection of human life.

Employers such as developers, consultants and contractors should be made aware that the payment of substandard salaries to engineers can lead to certain forms of corruption which may result in poor construction supervision and workmanship. Employers should also be aware that a decision to hire unskilled labourers or unqualified engineers for short-term financial savings will ultimately result in low-quality, high-vulnerability construction, and long-term financial losses.

The relevant authorities must require that all construction firms be solely liable over the design and construction works they have provided and must not be permitted to divert the liability to any individual or freelance engineer. Authorities should frequently provide engineers with the opportunity to anonymously report any unethical practices which they have observed and should either suggest or impose appropriate penalties. The accurate and consistent oversight by authorities during construction has the capacity to substantially reduce the frequency and scale of unethical practices within the industry.

Recommendation # 4: Improving Existing Buildings

It is clear that a substantial proportion of Tehran's older and vulnerable buildings are in urgent need of retrofit in order to improve their structural stability and to reduce the overall vulnerability of the city, however, it would not be feasible or practical to retrofit all of the existing vulnerable buildings. The buildings which are most at risk in each district should be identified and prioritized for retrofit. The central, eastern and southern districts including Districts 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17 have a significant number of buildings greater than thirty years of age, therefore, these districts should be prioritized for retrofit enhancement. Hospitals, fire-stations, schools, infrastructures, and lifelines are examples of the types of buildings and services which must be prioritized for retrofit and funded directly by the government. Hence, establishing special funding from the government for the strengthening of critical public buildings is the first step in enabling the enhancement of existing buildings.

The second step of enhancing existing buildings would be the implementation of government regulations which require all building owners to strengthen their existing buildings in accordance with the relevant seismic safety standards upon any application for new permits or facilities. Landlords may not be self-motivated to devote the financial capital necessary for the retrofit of existing vulnerable buildings, therefore, the government must strive to encourage landlords to do so by offering certain financial incentives such as low-interest loans and homeowner subsidies to promote this action within the private sector. Other efforts towards the improvement of existing buildings within the vulnerable districts could include conducting assessments to evaluate the costs and benefits of retrofitting aged vulnerable structures and facilities. Engineers and earthquake experts must provide their support to all parties by providing accurate details and specifications based upon existing resources and the absolute minimum cost for such projects without compromising quality or safety.

Although this research focuses upon prevention and mitigation to reduce earthquake risks, reconstruction should also be taken into consideration. The five principles of Ghafory-Ashtiany (1999) which include site selection, seismic design, construction materials, operation, and monitoring and quality control as presented in chapter two, can provide the most effective reconstruction plan after the occurrence of an earthquake in Tehran. All five stages should be diligently performed by constriction practitioners, researchers, and government agencies.

Recommendation # 5: Designing a National Insurance Program

Creating a coherent, efficient and reliable framework for earthquake insurance services along with the formation of an insurance system which would cover the majority of buildings in the city is an important policy for the reduction of earthquake casualties and losses. The growth of Tehran’s private insurance companies should be stimulated, particularly in the real estate sectors which currently lies under the purview of Iran’s central insurance company. This shift from public coverage to private coverage would aid in reducing the government’s financial liability. This change would help the government to focus its available funding on the enhancement of priority buildings and services on mitigating earthquake losses. Furthermore, this approach would facilitate greater transparency within the real estate sector as investors would be able to evaluate buildings more easily due to the availability private insurance policy records since property insurance is determined based upon the maximum value or market value of the asset's replacement cost.

Many countries such as the United States, France, Spain, New Zealand and Japan are highly experienced in real estate insurance schemes. Insurance models from these counties could be studied by the government of Iran to develop their own insurance schemes aimed towards disaster risk reduction, however, this research does not cover the details of insurance models established in other counties thus further research would be required in this regard.

Recommendation # 6: Support and Guidance from Tehran Municipality

Government entities such as the Tehran Municipality and district administration offices have an important role to play in the implementation of proposals presented in this study. Laws and regulations relating to seismic codes must be implemented and followed up diligently by municipality engineers. The Tehran Municipality must verify that only companies with valid work permits are conducting construction works and also that the performance of construction companies is reviewed regularly by municipality inspectors. Each building must have a dedicated electronic file containing all project design documents, drawings and any related specifications as a record that the building has been constructed based upon the relevant construction standards and seismic codes. The Tehran Municipality should only employ experienced, professional and technically competent engineers who are willing to accept responsibility over the projects which they supervise. Engineers employed by Tehran Municipality should participate in regular training programs and have opportunities for career advancement; employment benefits and adequate payrolls should be ensured to prevent susceptibility to corruption or bribery. The operating model of Dubai Municipality is a good example of a well-managed and efficient construction regulatory agency which could be studied by the Tehran Municipality as a template upon which reforms could be implemented. The author has twenty years of experience operating under the oversight of Dubai Municipality and can corroborate the high standards with which Dubai Municipality monitors construction engineering companies.

Engineers employed by district administrative offices and other authorities should have the sufficient knowledge and skills to assess structural designs including earthquake safety provisions. No permissions should be granted to use or occupy buildings without having checked the final construction of buildings and having verified that all design and approval documents are available for review by any concerned party. Construction licensing and building completion certification should be fully coordinated with other authorities such as utility services authorities, civil defence authorities and road management authorities in order to provide more efficient facilities and to aid in the implementation of integrated building management systems capable of shutting off gas pipelines or other hazardous systems during an emergency. In additional to risk mitigation regulations, the urban planning process should be managed by the Tehran Municipality and other relevant authorities whilst ensure that no other organizations with biased or special interests such as the Islamic Revolutionary Guard or army hold any influence over the planning process.

5.4. Difficulties and Challenges of Implementing the Recommendations

Implementation of the above recommendations is complicated and challenging as it involves a large number of individuals and legal entities and efficient coordination between these different groups. Some of the other challenges obstructing the effective implementation of these recommendations are:

1- **Disorganized governmental bodies** generate the conditions required for the advance of corruption. A unified and formidable national will is required to combat corruption in all stages of construction.

2- **A weak economy** is often accompanied by the proliferation of corruption, the manufacturing of substandard quality construction materials, low salaries for construction professionals, and unsafe or unregulated working environments.

3- **Mismanagement of human resources and qualified personnel** is a common in Tehran and the country as a whole, especially in the contract of disaster management.

4- **Separating any policy from technical issues**, in particular about disaster management, and accountability of, and respect to individuals for decisions that are taken before or will be taken in the future.

5- **Amalgamation of policies and technical issues** particularly in regards to disaster management and the accountability of individuals in positions of authority.

6- **Interference from external organization on the relevant disaster management bodies** and disruptions in the urban planning process and disaster management strategies due to lobbying and direct obstructions by political, security, economic and religious groups.

5.5. Personal Reflections – What I Have Learned Through This Research

There are several lessons relating to the development of earthquake-resistant buildings in seismically active regions which this research has taught me personally that I will be able to utilise in my active career in the construction industry. I have learned that ethical behaviour in construction practice plays an important role in the development of buildings with a high-quality of workmanship and materials in order to deliver the appropriate structural stability parameters. I understand that my professional work is vital to lives of others and that corruption may result in the loss of life and assets. Members of the public place trust in me and believe that buildings constructed by professional will protect them against hazards such as earthquakes.

I have also realised that my beliefs in the context of achieving low-cost construction is not synonymous with low-quality construction, something which have always explained to my clients. Clients often feel that high-quality buildings require expensive construction materials and that construction codes are not a concern in high-cost buildings as quality is assured. Hence, I should never accept the opinion of developers in that construction practitioners do not necessary need to comply with construction codes in all cases since these codes may not be pertinent to the scale of their projects.

I have learned that the construction industries in every country are globally linked and that poor economies or international trade sanction imposed upon counties such as Iran can prevent reputable manufactures of construction materials and systems in providing their goods or services and may face heavy penalties if found to be doing so. Hence, construction practitioners in Tehran are often forces to utilize locally produced construction materials which may be of substandard quality since Iran's manufacturing standards of construction materials do not comply with international standards.

I have learned that the supervision and inspection of construction works should be carried out by licensed and registered construction engineering companies rather than by freelance inspectors. In the United Arab Emirates, any specialist firm involved in a project must be under the supervision of a local consultant so that authorities may check each stage of the project and advise the local consultant if any modifications are required, the local consultants shall then coordinate with the relevant specialists. This enables the authorities to easily monitor each stage of construction and ensures efficient communication between concerned parties. In contrast, constriction supervision in Tehran is conducted by freelance engineers whom have been approved by the local authorities. Each engineer is provided with a quota for building supervision which is referred to as a monitoring sheet; any specialist such as civil engineers, architects or mechanical engineers may use these monitoring sheets as needed. This policy generates several problems including: (1) Poor coordination between engineers since several independent engineers may be active in the same projects but are employed separately. (2) A lack of leadership within projects due to conflicts of opinion between the various engineers during inspections. (3) It has been reported that some engineers offer their blank monitoring sheets for sale to non-expert individuals as a method of generating a higher income, this not only increases corruption but also leads to the approval of unsupervised low-quality construction. (4) Supervision by individuals catalyses corruption within the industry; the surveillance of corruption committed by individuals is more difficult than the surveillance of corruption committed by licensed and registered companies.

Another lesson which I have learned is in regards to the empowerment of certain organisations. It often occurs that municipal engineers are prevented by certain government agencies in conducting their supervision duties as these government agencies believe that the municipality does not have the authority to interfere with their construction projects. The Islamic Revolutionary Guard Corps, for instance, are highly active in construction and believe that all stages of design, construction, and supervision should be conducted by their own engineering firms without any oversight from other companies and/or authorities; they do not comply with government regulations and have their own standards of construction practice.

Furthermore, I have learned that universities and educational institutions play an important role in the intellectual development of engineering students and must instil positive values and principles of ethics in their students from the onset of their academic and professional careers. Universities and institutions have an important role to play in promoting innovation and advancing the technical knowledge and skill of their engineering students and graduates. However, the engineering students and graduates themselves are the ones who must demonstrate their innovation and technical knowledge. Engineering students and graduates must endeavour to frequent the relevant seminars and programs offered by educational institutions. They must acknowledge that the development of further knowledge is a perpetual process and does not end upon achieving a certain degree of academic qualification. Finally, I realized that preventing and managing hazards, such as earthquakes, which is leading to major disaster, should be done before the incident, and not after.

5.6. Limitations to The Research

A secondary objective of this study is to provide useful data for future studies relating to the role of the engineering community in coping with the impacts of hazardous events such as earthquakes, however, they may be some limitations in this regard. One such limitation experienced during this research was the inaccessibility of certain data collected by local authorities which had been deemed to be confidential; this data could provide valuable information pertaining to the economic damages caused by previous earthquakes and/or the role of authorities and government in the reduction of disaster impacts. A further research limitation presented itself during the qualitative interview process as some respondents were unwilling to discuss certain topics such as ethical issues or the neglect of authorities in order to avoid any personal conflict; a duality of behaviour was observed in some respondents during the interviews. One other constraint was the limited time available to collect research data since the author was engaged in full-time employment in Dubai, United Arab Emirates, and had to travel back and forth from Tehran on multiple occasions to collect the data and conduct interviews; this was made more time-consuming once it was realized that the web-based quantitative questionnaire was not successful in obtaining the required data. Furthermore, a lack of access to female engineers was another significant limitation in this study. It seems that there are not many female graduates employed within Tehran’s construction industry, either due to a lack of interest or possibly due to certain cultural tendencies. Understanding why females do not commonly participate in Tehran’s construction activities could be another subject of future research.

5.7. Scope for Further Research

This research was focused upon construction practitioners as individuals. Further studies are required to address professional companies such as consultants and contractors and their roles in the reduction of Tehran's earthquake risk. These further studies on this subject would help researchers to understand why professional companies in Tehran are not committed to designing and supervising the construction of buildings resistant to the impacts of hazards such as earthquakes. Another important area of study to be addressed in future research are the ethical issues common within Tehran's construction industry. Tehran's construction engineers often do not conduct their business as per any particular ethical standards; this may be because they do not have a standardized system in place to comply with. Additional studies are necessary to raise the level of knowledge within Tehran's engineering communities regarding the implementation of construction codes and ethical practice. Furthermore, the establishment of a standardized insurance system and a clearly defined framework for providing reliable construction insurance is needed. Further studies could assist in determining which insurance system would be more feasible and appropriate for Tehran's society. The role of academic institutes and local universities is critical in assessing the laws and regulation governing Tehran's construction practice against international standards and in providing recommendations for improvement. Therefore, further research is needed to understand why some graduate engineers do not possess sufficient levels of technical knowledge or skills and to determine what should be done by universities to ensure that graduate engineers are properly educated.

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ANNEXURE : QUESTIONNAIRE

Section 1: Demographic Information

Please be aware that all the information you provide us with is anonymous, and we will only use this information for the purposes of this study. We ask about this information to determine how representative our sample is of the general population.

What is your gender? (Tick only one)

- ○ Male
- ○ Female

Into which age bracket do you fall? (Tick only one)

- ○ 20 - 29 years
- ○ 30 - 39 years
- ○ 40 - 49 years
- ○ 50 - 59 years
- ○ 60 - 69 years
- ○ 70 - 79 years
- ○ + 80 years

What is your highest educational qualification? (Tick only one)

- ○ No formal qualification
- ○ Secondary school qualification
- ○ Diploma
- ○ University undergraduate degree
- ○ University postgraduate degree

What group do you belong to? (Tick all that apply)

- ☐ University professor
- ☐ Municipality employee
- ☐ Surveillance engineer
- ☐ Member of Tehran's construction engineering organisation
- ☐ Building Official employee
- ☐ Contractor

Are you a member of a professional body? (Tick all that apply)

- ☐ Member of Iranian society of Civil Engineers (IRSCE)
- ☐ Member of Institute of Project Management Professionals(IPMP)
- ☐ Member of Iranian Society of Consulting Engineers(ISCE)
- ☐ Member of Iranian Earthquake Engineering Association (IEEA)
- ☐ Member of Iran Project Management Association (IPMA)

☐ Member of International Institute of Earthquake Engineering and Seismology (IIEES)

☐ Member of Iranian Society of Structural Engineering (ISE)

☐ Member of Institute of Civil Engineering ICE (UK)

If you are a member of Institute of Civil engineering (ICE), which status is your membership? (Tick all that apply)

☐ Graduate Membership

☐ Technician Membership (TMICE)

☐ Incorporated Engineer (IEng)

☐ Chartered Engineer (CEng)

What is your physical area of jurisdiction? (Tick all that apply)

☐ 1st district of Tehran

☐ 2nd district of Tehran

☐ 3rd district of Tehran

☐ 4th district of Tehran

☐ 5th district of Tehran

☐ 6th district of Tehran

☐ 7th district of Tehran

☐ 8th district of Tehran

☐ 9th district of Tehran

☐ 10th district of Tehran

☐ 11th district of Tehran

☐ 12th district of Tehran

☐ 13th district of Tehran

☐ 14th district of Tehran

☐ 15th district of Tehran

☐ 16th district of Tehran

☐ 17th district of Tehran

☐ 18th district of Tehran

☐ 19th district of Tehran

☐ 20th district of Tehran

☐ 21st district of Tehran

☐ 22nd district of Tehran

How long have you lived in Tehran?

Section 2: Hazards in General

In this section, we'd like to know your thoughts about hazards in general

On a scale from 1 to 5, how likely do you think it is that each of these events will affect you? (Tick one for each hazard)

	1	2	3	4	5
Bad weather (e.g. cyclone, storm, the wind, heavy rainfall)	○	○	○	○	○
Snowstorm	○	○	○	○	○
Earthquake	○	○	○	○	○
Landslide	○	○	○	○	○
Climate change / Global warming	○	○	○	○	○
Crime	○	○	○	○	○
Building fires	○	○	○	○	○
Vehicle accidents	○	○	○	○	○

Infrastructural failure	○	○	○	○	○
War / terrorism	○	○	○	○	○
Other hazards (please specify)					

Have you ever been affected by any of the previously mentioned hazards? (Tick only one)

- ○ Yes, I have had direct experience (e.g. damage, injury, loss of utilities)
- ○ Yes. I have had indirect experience (e.g. was inconvenienced, couldn't travel)
- ○ No (go to the next question)

If you have been affected in the past, please write down the type of event(s) that have affected you:

Section 3: Preparation For Earthquakes

In this section, we'd like to know your thought about earthquakes and learn more about your attitudes to earthquake's preparation.

Please describe the extent to which you agree or disagree with each of the following statements:

	Strongly agree	Agree	Neither agrees nor disagree	Disagree	Strongly disagree
Earthquakes are too destructive to bother preparing for	○	○	○	○	○
A serious earthquake is unlikely to occur during my lifetime	○	○	○	○	○
Preparing for earthquakes is inconvenient	○	○	○	○	○
It’s hard to prepare for earthquakes	○	○	○	○	○

Have you heard, seen or received any information about how construction practitioners should prepare for a potential earthquake?(tick all that apply)

☐ I haven't heard, seen or received any information
☐ Colleague where you work
☐ Media (TV, radio, newspapers, magazines, Internet)
☐ Insurance company / agent
☐ Schools and universities
☐ Community meetings, seminars or workshops
☐ Construction engineering organisation
☐ Disaster management organisation
☐ Other (please specify)

Do you feel that you are informed enough to be able to plan adequately for reducing the impact of potential seismic hazards in the city of Tehran? (Tick only one)

○ Yes, completely ○ Yes, slightly ○ No

Please read each of the following statements and describe the extent to which you agree or disagree

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There may be earthquakes, but they won't be that bad	○	○	○	○	○
The location of the earthquakes will be far away from our district and will have little impact on us	○	○	○	○	○
The buildings in our district are earthquake-proof buildings, and they are safe	○	○	○	○	○
Escape zones for earthquake emergencies are not planned in the buildings	○	○	○	○	○
Disruption of water, infrastructure damages, and power failure have most impact on us	○	○	○	○	○

Disruption to other services such as communication, gas, sewerage and fire have most impact on us	○	○	○	○	○
The potential impacts would depend on the exact nature of the event, including the time and season	○	○	○	○	○

In regard to what happens within the construction practitioners' community, please describe the extent to which you agree or disagree with each of the following statements:

	Once a week or more	A few times a month	Once a month	A few times a year	Rarely	Never
I talk about earthquake problems and issues regards to construction practice with the other construction practitioners	○	○	○	○	○	○
I attend seminars relevant to construction practice and its impact to reduce earthquake problems and issues	○	○	○	○	○	○
I have worked with other construction practitioners to find ways of improving construction practice for future earthquakes	○	○	○	○	○	○

Section 4: The Impact of Earthquakes

In this section, we'd like to know your thoughts about built environment and the role of building construction practitioners in reducing earthquake impacts.

Please rate the extent to which your district's building constructed with each of the following structural types.

	Less than 5 percent	5 – 25 percent	25 - 50 percent	50 - 75 percent	75 - 100 percent
Wood	○	○	○	○	○
Steel	○	○	○	○	○
Reinforced concrete	○	○	○	○	○
Reinforced concrete or steel with unreinforced masonry infill walls	○	○	○	○	○

Reinforced masonry	○	○	○	○	○
Unreinforced masonry (fired brick, concrete block, and shaped stone)	○	○	○	○	○
Lightweight shack (e.g. corrugated iron sheet)	○	○	○	○	○

What is average building age in your district(s)? (Tick only one)

○ Less than 5 years
○ 5 - 10 years
○ 10 - 20 years
○ More than 20 years

What is the typical height of building in your district(s)? (Tick only one)

○ Low rise building (one to three stories)
○ Medium rise building (four to seven stories)
○ High rise building (eight or more stories)

Please rate the quality of construction workmanship in your district(s)? (Tick only one)

○ Excellent quality, effective supervision of seismic elements of construction

○ Good quality, some supervision of seismic elements of construction

○ Moderate quality, no supervision of seismic elements of construction but skilled workers

○ Poor quality, no supervision of seismic elements of construction and unskilled workers

Please rate the quality of materials used in building construction in your district(s)? (Tick only one)

○ Good quality materials, and proper material inspection

○ Good quality materials, but no proper material inspection

○ Poor quality of materials, and no material inspection

Please describe the extent to which you agree or disagree with each of the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There are rules and regulation to follow in relation to seismic hazards	○	○	○	○	○

Construction practitioners get enough training to perform their job adequately.	○	○	○	○	○
The plan time schedule for each building construction is reasonable.	○	○	○	○	○
Construction practitioner's performance will be measured by the authorities or the construction industry	○	○	○	○	○
Construction practitioners earn enough money to perform their job.	○	○	○	○	○
Construction practitioners do their jobs fairly and justly.	○	○	○	○	○

Please describe the extent to which you agree or disagree with each of the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There are strict regulations for building's safety system	○	○	○	○	○
There is regular, efficient and well-enforced surveillance in observing buildings' safety laws	○	○	○	○	○
The safety infrastructure of the buildings are well designed and executed	○	○	○	○	○
Buildings are equipped with firefighting system and emergency plan	○	○	○	○	○
Buildings are equipped with BMS(Building Management System) to deal with building damages such as having power, gas, and communications off	○	○	○	○	○

To what extent do you think each of the following unethical practices has an impact on construction projects in Tehran? Please rate the incidence of each practice from 1 (not at all) to 5 (a great deal).

	1	2	3	4	5
Overpricing	○	○	○	○	○
Bid cutting	○	○	○	○	○
Poor documentation	○	○	○	○	○
Late and short payments	○	○	○	○	○
Subcontractors' lack of safety ethics	○	○	○	○	○
Unfair treatment of contractors in tender/final account negotiations	○	○	○	○	○
Competitors' overstatement of capacity and qualifications to secure work	○	○	○	○	○
Competitors' falsification of experience and qualifications	○	○	○	○	○
Non- adherence to regulation	○	○	○	○	○

Section 5: Responsibility for Preparation for Earthquakes

In this section, we'd like to know your thoughts about the authorities (e.g. Government, Municipality, Society of Engineering, Disaster Management Organisation and Construction Community) responsibilities and their role in reducing earthquake impacts.

Please rate (from 1 = not at all prepared to 5 = very prepared) the extent to which you perceive each of the following stands ready to deal with an earthquake

	1	2	3	4	5
How well prepared is the Government for a major earthquake?	○	○	○	○	○
How well prepared are contractors for a major earthquake?	○	○	○	○	○

To what extent is the district municipal council empowered to monitor construction practice?	○	○	○	○	○
How well prepared are Tehran construction engineering professionals for a major earthquake?	○	○	○	○	○
To what extent are consultants empowered to monitor construction practice?	○	○	○	○	○

In regard to the responsibility for earthquake-proof buildings, please describe the extent to which you agree or disagree with each of the following statements.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Strongly agree
I feel responsible for the regulation in construction preparations for a major earthquake	○	○	○	○	○	○
Municipalities are responsible for the regulation of engineering practice in preparation for major earthquake	○	○	○	○	○	○
The Government is responsible for the regulation of engineering practice in preparation for major earthquake	○	○	○	○	○	○

Are there regulations to monitor or control the construction on unstable land and fault zones? (Tick only one)

○ There are complete regulations, and there is enforcement in obeying them

○ There are complete regulations, but there is no enforcement in obeying them

○ There are incomplete regulations

○ There are no regulations

What is the renewal rate of buildings in your district(s)?

○ 0 – 20 percent ○ 21 – 40 percent ○ 41 – 60 percent

○ 61 – 80 percent ○ 81 – 100 percent

Do you think you have the necessary regulatory support to conduct seismic retrofit? (Tick only one)

○ Yes

○ No

○ I am not sure

○ I don't know

What is the source of funding for seismic retrofitting? (Tick only one)

○ Owner fund

○ Loan from financial institution

○ Loan from Government

○ Loan from insurance

Please describe the extent to which you agree or disagree with each of the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Strongly agree
There are enough space near your district for mass care and sheltering of victims and survivors after an earthquake	○	○	○	○	○	○
There is a standardized process in order to examine the safety of buildings immediately after an earthquake	○	○	○	○	○	○

To what extent do construction practitioners take each of the following into account in preparing for the impact of earthquakes on buildings? Please rate the impact of each statement from 1 (not at all) to 5 (a great deal).

	1	2	3	4	5
Cost	○	○	○	○	○
Skill or knowledge of staff	○	○	○	○	○
Time needed to prepare	○	○	○	○	○
Materials	○	○	○	○	○
Co-operation with others	○	○	○	○	○